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ELEMENTS
— OF —
SCIENTIFIC AND PRACTICAL
AGRICULTURE.

ADAPTED TO THE REQUIREMENTS OF SCHOOLS AND
THE AGRICULTURAL PUBLIC.

— BY —
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BALTIMORE, MD.:
THE BALTIMORE PUBLISHING COMPANY, PRINTERS,
No. 106 E. Baltimore Street.

1887.

"The fundamental principles of plant-growth and tillage, if not occupying more than an hour a week in the school, would exert a beneficial and powerful educational influence, and add untold riches to the wealth of our people."

—DR. F. M. HEXAMER.

"But it is not the mere practical utility of these agricultural truths which is of importance; their influence upon mental culture is most beneficial, and the new views acquired by the knowledge of them enable the mind to recognize in the phenomena of nature proofs of an infinite wisdom, for the unsathomable profundity of which, language has no expression."

—BARON LIEBIG.

PREFACE.

IN the following treatise it has been the aim of the author to render the various investigations as simple, natural, and easily understood as possible, and to establish and illustrate them in a plain and familiar manner, without descending to mere puerility. He trusts the methods by which he establishes the processes causing the first soil on the face of the earth, the formation of the secondary rocks, and succeeding formations, and the modes he has employed in explaining the theory and practice of farm cultivation, as well as the causes of the different kinds of soils, etc., will divest those subjects of much of the mystery that has long enveloped them.

In like manner, using freely what has been done by previous writers, he has endeavored to simplify those elementary principles which underlie the various operations of practical and profitable husbandry.

Much absolute novelty, except in the mode of exposition, cannot now be expected in a work on the Elements of Scientific and Practical Agriculture. Some of the matter, however, the author thinks, is entirely new, while others are for the first time systematically arranged, clearly developed, and fully explained in familiar language.

With regard to the useful application of the science of agriculture to practical farming, there is no difference of opinion among men of sound judgment, and it is only with that subject this elementary work has any concern.

The use of technical terms has been avoided as much as possible. The derivation and meaning of a few words, which may not be familiar to all, have been given at the end of the

book for the convenience of those who may not have a dictionary at hand.

Questions have also been added, which are merely suggestive. When the work is used for a text-book, the teacher should be particular to bring out the salient points of each subject, and encourage the pupil to amplify and illustrate his statements in his own words, bearing in mind that the most interesting subject becomes dry and irksome if not thoroughly understood.

It may be assumed as self-evident that agricultural instruction, to be a national benefit, must be accessible to the people, especially the cultivators of the soil. It may also be assumed that this end can be best attained through the public schools, by means of a suitable text-book. With this end in view, this work is given to the public. How successful the author has been in supplying the need, the people must judge.

The desire of the author has been to supply a useful, reliable, and comprehensive book at as moderate a price as possible; and he believes he has given in this work a very large amount of matter in proportion to its size.

CUMBERLAND, Md., February, 1887.

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ELEMENTS

—OF—

SCIENTIFIC AND PRACTICAL AGRICULTURE.

CHAPTER I.

CHIEF OBJECT OF AGRICULTURAL SCIENCE.

THE various operations employed in **cultivating** the land, so as to make it yield vegetable food abundantly, is called **Agriculture**. The great object of agriculture is to **produce** from a given space the greatest **quantity** of certain kinds of **vegetation**, with a due regard to the **quality** of the produce, at the **lowest cost**, without exhausting the soil.

The sciences of **Chemistry**, **Botany**, and **Geology** are of great value and importance to the cultivator of the soil, as they furnish the means of knowing the different **classes** of agricultural plants, how they feed, the quantities of the different substances each kind of plant requires, from whence they obtain their food, from whence the soil came in which they grow, and how the farmer **can best aid** the plant in getting an **ample supply of food**.

We propose to call to our aid only so much of these sciences as may be deemed necessary for the correct understanding of the **growth of plants**, the **tillage of the soil**, and the reasons for the **practice of intelligent farmers**.

Metaphysics and the fine arts were carefully studied by the Greeks and Romans, in which they reached a high standard of perfection; but the natural sciences, the offspring of the inductive system, were ignored by them.

Until 1820 (Sir Humphrey Davy) and 1840 (Baron Liebig) agriculture had **no scientific basis**; it was a mere **experimental art**. Effects were ascertained, but causes were unknown. Happily, chemical analysis and philosophic sagacity at last shed light on the subject. To science we owe most of the comforts of life—such as health, clothing, literature, and locomotion. There is no good reason why the production of our greatest necessity—**food**—should be **excluded** from its influence.

Agricultural labor, beyond any doubt, develops man's physique; but it has also been said that it develops the **muscles** at the **expense of the brain**. Under the scientific and practical system of farming, no such charge can be maintained; because both brain and muscle are **stimulated to activity** by the multiplicity of operations, and the varied **intellectual** inquiries necessary to bring the cultivation of the soil and the growing of crops to a successful issue. **Each** is thus accorded fair play, and **both** attain a well developed proportion.

The Bible says: "The sleep of a laboring man is sweet." If the farmer could but realize how greatly blessed he is in this particular, by the character of his labor and surroundings, he would not desire to exchange places with the nerve-strained sons of commerce, or the followers of the phantom, Dives—the merchant princes of the cities, or the brokers of Wall street. No one leads a life more in harmony with the divine command given to our first parents than the tiller of the

soil; and no one can follow a more **peaceful, enjoyable, and healthful pursuit**, or has a freer and fuller opportunity for the profitable exercise of intelligence and contemplation of the wonderful goodness of God.

CHAPTER II.

THE GROWTH OF PLANTS.

✓
PLANTS can only grow when they have a proper supply of the **materials** they need for building up their various parts; they, like animated beings, **require food**; and although in a wild state, they can obtain all the nourishment they require from the air, and from the soil in which they grow; yet, when we produce them in **particular places**, and in **great quantities**, for the use of man, we must take great care that they be supplied with food proper for them, and sufficient in quantity. We shall endeavor, in this work, to explain clearly **the principles** which **regulate the supply of food** to the plant, and the way by which the farmer is able **to assist the plant** in obtaining it.

The prime object of agriculture, then, **is to grow and multiply plants**; therefore, it will be necessary for us to inquire, at the outset, what plants are **composed of**, and **how they grow**.

It will be observed that all agricultural plants, such as wheat, clover, beets, potatoes, etc., consist of **two principal parts**. The **root**, which is pale colored, growing downward into the soil, and irregularly branched; **the stem**, or top, which is generally green, grows up into the air, sending out branches in a more regular manner, and produces leaves, flowers, and fruit. Some plants are grown by the farmer for their **roots**,

as turnips; others for their **leaves** and **stems**, as clover and grass; and others for their **fruit** and **seeds**, as corn, wheat, beans, and peas. The farmer, therefore, talks of root crops, green crops, grain crops, and fruit crops.

Some roots are thick, and grow straight downwards, sending off slender branching fibres, as carrots and beets; others are entirely fibrous, as the grasses. The uses of the roots are to take in **nourishment**, and **fix** the plant in the soil. Roots are sometimes much longer than the stems. The roots of wheat have been traced to a depth of **seven feet**, and those of corn have been known to extend a distance of **fifteen feet** from the **stem**. The ends of the root-fibers are fine and delicate, and covered with minute hairs, **into** and **through which** the nourishment of the plant **enters**, and finds its way up into the stem.

The stem generally grows upward into the air; but in a few the stem lies on the surface, and in others it runs partly underground. The potato is, in reality, a thickened part of an underground stem, the eyes of which are simply buds. The stem is sometimes hollow, as in wheat, and is always made up of bundles of **long cells** and vessels, through which **water** and other **substances**, taken in from the soil by the roots, pass up into the **leaves**.

The most important organs connected with the life and growth of all plants are their **leaves**. A leaf is a thin layer of minute cells spread out to the air, strengthened with ribs or veins, made up of stouter cells or vessels, and covered on both sides with a fine membrane, nearly transparent. In these membranes are minute openings, called pores, through which the plant takes in **air** and gives off **water** and **gases**.

When a plant is full grown, flowers appear upon its branches. Some plants, as the carrot and turnip, take

two years to produce their flowers. The first year the root grows thick and fleshy, the tops bearing only leaves. The second year the plant pushes forth a strong stem; it is then said to have "**run to seed.**" The store of nourishment laid up in the fleshy root, during its first year's growth, is consumed in producing the flowering stem, fruit, and seed, after which the root will be found stringy and spongy, and **useless for food.**

All agricultural plants put **forth flowers**, but some are very small and dull colored. When the outside of the flower falls off, the middle part grows into fruit, which contains the seed. A grain of wheat is properly a **fruit** containing one seed; a bean-pod is a fruit containing several seeds.

CHAPTER III.

SEEDS AND THEIR GERMINATION.

A **SEED** contains the young plant and **sufficient nourishment**, usually consisting of starch or oil, to support the young plant until it is able to **support itself.** The embryo consists of a **plumule**, or young bud, from which the stem will grow up into the air; a **radicle**, or young root, from which the main root will grow down into the soil; and one and sometimes two seed-leaves, which push up above the soil and become the first **green leaves** of the plant.

Three things are necessary to enable a seed to begin to grow: (1) **Moisture**, which is absorbed by the seed, causing it to enlarge and burst its hard outside case; (2) **Warmth**, of which some require much more than others in the first stage of germination; and (3) **Air**,

from which the seed derives oxygen and carbonic acid gas. When a seed, therefore, is kept moist and warm in the air, it will begin to grow, no matter whether it be placed in the soil or not; but, as it has to obtain most of its food from the soil as soon as its own store is exhausted, it is best to sow it **in the soil at once**, being particular to see that it can obtain enough moisture, warmth, and air. The seed then becomes swollen, the young bud enlarges and bursts through the outer skin, the plumule rises into the air, carrying with it the seed-leaf or leaves, or opening out its young green leaves to the sunlight while the radicle descends into the soil, sending off minute branching fibers. The **oxygen** of the air acts upon the stored-up food in such a way that the oil and starch are converted into a kind of **sugar**.

That **solid substances** can be **dissolved** in water, is difficult for the learner to realize; yet we see instances of it every day in the case of easily dissolved substances, as **sugar** and **salt**. A lump of sugar put into a glass of water soon disappears; still we know it is there, and its presence is easily detected by the taste. Most of the sparkling spring water which we drink has **lime**, **magnesia**, **iron**, and other substances in it; yet it looks clear and bright to the eye. All the substances which constitute the food of plants must be dissolved in water, in this **clear and complete** manner, before **they can be taken up** by the rootlets of plants.

CHAPTER IV.

ROOTS OF PLANTS AND HOW THEY TAKE IN FOOD.

IF you loosen the earth around and under the root of any young plant, and carefully pull it up, wash off the soil gently in a pan of water, and then examine the root, you will observe it to consist of a number of **whitish fibers**, growing finer and whiter towards the tips. These fibers, put under a strong magnifying glass, will be seen to be **hollow tubes, closed at the ends**, and having very thin walls. It is through the delicate skin of these hairs on the root-fibers that the plant absorbs the clear water in which its food is dissolved. As the roots grow older and thicker, they lose their hairs, and their outermost layer becomes hard and forms a rind or bark, while the taking in of the water containing the food is carried on by the hairs and cells, upon newer fibers, branching out and spreading wider and deeper into the soil.

In **poor soils** root-hairs are found to be **more abundant** than on fibers growing on good soil, because more effort is required to be put forth by the plant in finding food from the thinly distributed nourishment than in good soil, where all the materials required are at hand in abundant supply. But the young student naturally asks: If no openings exist in these hair-fibers, how can the water get in? The following experiment will remove any doubt that may exist on this point: Take a small glass funnel and tie tightly over the mouth of it a piece of bladder or very thin India rubber, such as is used for children's

balloons; now pour into it some water, in which sugar or salt is dissolved, and dip the covered end into a basin of clean water. After a time it will be found that the **liquid** in the tube **has risen**, and, on tasting the water in the basin, some of the sugar or salt will be found to have **penetrated** the **membrane**. Thus it is proved that fluids, separated by a membrane, are able to pass through and diffuse into one another, though there are no holes to be found in the dividing membrane, even by the most powerful microscope.

CHAPTER V.

WHAT PLANTS ARE COMPOSED OF.

WE shall now examine into the **composition of plants**, and ascertain what becomes of the water and substances, held in solution, which they have drunk up or absorbed. In a green growing plant the most abundant substance is water. Fresh meadow grass contains from seventy-five to eighty-five per cent. of water, while in turnips more than ninety per cent. is found. Therefore, one hundred pounds of fresh grass, when made into hay, will weigh about twenty-five pounds; and, if completely dried in an oven, will weigh only about fifteen pounds.

The water contained in the plant is **not stationary**, but is passing through the plant, from cell to cell, until it reaches the leaves, where, being spread out to the air, it is quickly evaporated through the minute openings, which we before explained as abounding in its covering membrane. A healthy medium sized cabbage has been found to evaporate nearly a pint of water in twelve hours; and it has been calculated that an acre of

cabbages will give out in the course of twelve hours, by evaporation, more than ten tuns of water.

The **frame-work** of the plant, of which the walls of the cells are made, consists of a substance called **cellulose**, the most familiar form of which we see in **paper** or hornets' nests. We may consider, then, the plant to be constructed and built up of an infinite number of minute paper boxes, closed on all sides; and the water, with its contents, oozes through the sides of these boxes, from one to another, till it reaches the leaves; and on its way back from the leaves, **each retains** that portion of the nutriment which it needed and passes the rest on to its neighbors.

Another very abundant substance is **starch**. This is in the form of minute grains, stored up in many of the small boxes or cells, which are often packed full of them. A potato consists almost entirely of cells packed and crowded full of starch granules. Starch can be very easily **converted** into sugar, and in many plants sugar is very plentiful, as in the sweet fruits, sugar cane, in the cells of the beet-root, and sap of the sugar maple. When barley is made into malt, the warmth and moisture cause the starch to be turned into sugar.

CHAPTER VI.

THE ORGANIC COMPOUNDS.

ALL the substances mentioned in the former chapter, namely, **water, cellulose, starch, sugar, and oil**, are found by chemists to be composed of **three elements**, or simple substances, viz., **carbon, oxygen, and hydrogen**. **Water** is composed of oxygen and hydrogen; cellulose, sugar, starch, and oil are each

composed of carbon, oxygen, and hydrogen, and, in the plant, are often **changed** from the one to the other.

There are two substances in the plant which must be specially mentioned, and which are made up of four elements, viz., **carbon, oxygen, hydrogen, and nitrogen**. The first of these substances is called **protoplasm**, a kind of jelly-like material found in all living cells, which, under the microscope, is seen to turn round and round in its cell, and is really the life substance in the plant; and the second is called **chlorophyll**, or leaf-green, which is formed out of protoplasm by the action of sunlight, and is found in all the green parts of the plant. If a plant is kept from the light it turns yellow and then white. You have all witnessed this in the growths made by potatoes in the cellar, and the blanched stalks of celery, which is caused by earthing them up; because, in the absence of light, no leaf-green is formed.

All the substances of the plant which we have been considering, whether formed of three elements or four, are called **organic compounds**, because they go to make up the principal part of all organized beings—that is, plants and animals having special members or organs.

✓ CHAPTER VII.

THE INORGANIC SUBSTANCES.

If we take a plant and **dry it**, and then **burn it**, all the **organic** substances disappear and mingle with the air, again to be used by other plants; and the **inorganic**, or fixed substances, remain as ashes, which are, in reality, the **mineral matters** contained in the plant; and these, when analyzed, are found to consist

of a number of compounds which are found in many minerals as well as in animals and plants.

The following table shows the materials found in plants:

ORGANIC.		INORGANIC.
NON-NITROGENOUS.		Silica.
Carbon, Oxygen, Hydrogen only.....	Starch.	Potash.
	Gum.	Soda.
	Sugar.	Lime.
	Cellulose (or woody fiber).	Phosphoric Acid.
	Oil.	Carbonic Acid.
NITROGENOUS.		Sulphuric Acid.
Carbon, Oxygen, Hydrogen, and Nitrogen.. ..	Albumen.	Magnesia.
	Fibrine (gluten).	Oxide of Iron.
	Casein (legumen).	Chlorine.

Most of these are the common names of substances with which you are familiar.

Potash is so called because it was first obtained by **burning plants in a pot**, then leaching the ashes and evaporating the water. Iron oxide is the **rust** seen upon iron when exposed to the air. Silica is the substance which we see in **white sand**, flint, and quartz-crystals. Ammonia is so called from its having been obtained from the camel-yards near the Temple of Jupiter **Ammon**, where the worshipers of that idol had congregated for many years; it is also called harts-horn, because of its having been obtained from the horns of the deer. All the inorganic substances named above contain **oxygen**, except **chlorine** and **ammonia**. Chlorine, when liberated from its compound, is a yellow, choking gas, but in the plant it is combined with potash or soda; when combined with the latter, it is called **chloride of sodium**, known to every person

NOTE.—Ammonia is composed of Nitrogen and Hydrogen, and belongs to the organic elements.

as **common salt**. From the strong affinity which chlorine has for water, if it be set free in a cellar which is damp and mouldy, it will destroy the mould and render the cellar sweet and healthful. If an earthen vessel, with about two pounds of common salt, be placed in a cellar, and an ounce of sulphuric acid poured over it, the chlorine will be set free from the soda and fill the cellar, which should be tightly shut up for four or five hours. You must be careful not to breathe the gas, and to aërate the cellar thoroughly before entering it. A drink of water is the antidote to the effects caused by inhaling the gas.

The acids named in the table, when found in the plant, are combined with minerals, and are what chemists call **phosphates, sulphates, and carbonates**. Silica, also, sometimes forms an alliance with minerals, and these compounds are called **silicates**. We have, therefore, **phosphate of potash, phosphate of lime**, a very important compound, which constitutes the chief value of bone as a fertilizer; also, we have the **sulphate of potash, sulphate of magnesia** (epsom salts), **sulphate of lime** (gypsum and plaster of paris), **corbonate of soda**, and **carbonate of lime** (marble and chalk).

CHAPTER VIII.

PLANT FOOD.

WE may now take up the subject of plant food. All these substances, found in plants that have grown from very **small seeds**, must have been **obtained** by them from without; and, to enable them to grow and be thrifty, they **must be in reach** of these substances.

As soon as plants have used up the nourishment provided for them in the seed, they require a supply of the following **organic materials** to build up their soft parts, viz.: Oxygen, hydrogen, carbon, and nitrogen; and the inorganic materials, to build up their frame-work or skeleton, viz.: Potash, soda, magnesia, lime, iron, phosphoric acid, sulphuric acid, silica, and chlorine.

Full-sized, healthy plants have been grown to **complete maturity, without any soil at all**, by suspending them, with their roots dipping, into a vessel of water in which has been dissolved a supply of all **these articles** of plant food. Some exceedingly interesting experiments have been made in growing plants artificially, with food specially prepared and dissolved in water. Some may be desirous of trying the experiment, and, as it will be instructive as well as interesting, we shall describe in the next chapter one of the best modes of procedure, which has been successfully tested.

It is of great importance to keep in mind the **sources** from which plants derive their food:

First—Air. The air is mainly composed of two gases, nitrogen and oxygen, with a small portion of carbonic acid gas, which is itself a compound of oxygen and carbon, and still smaller quantities of ammonia and nitric acid; the former of which contains nitrogen and hydrogen, and the latter nitrogen and oxygen. Careful experiment has shown that **none** of the free nitrogen of the air is **taken in by plants**, and that, small as the carbonic acid is in the air, it is the source of almost all the carbon found in plants. The leaves absorb carbonic acid from the air, and then, under the influence of sunlight upon the leaf-green, the carbonic acid is separated into its elements (carbon and oxygen); the

carbon is **retained** by the plant, which uses it in forming cellulose, starch, sugar, and other substances; while the oxygen is **given out** to the air.

Oxygen is also, at times, absorbed from the air, especially when the plants are growing rapidly and coming into flower. The ammonia and nitric acid are washed down into the soil by the rains, and then taken in by the roots, supplying the plants with a small portion of nitrogen.

Second—**Water**. Pure water is a combination of oxygen and hydrogen. When water is used by the plant, its duty is chiefly to convey other matters, which it holds in **solution**, to the root; but some of it is divided up and used by the plant in forming the starch and other organic matters. Rain water is the purest natural water known, having nothing dissolved in it but what it has washed down out of the air; but, as soon as it enters the soil, it begins to dissolve the mineral matters there, and carries them to the roots of plants.

Third—**The soil**. We have now seen what plants obtain from air and water; the rest of the nitrogen, and all the mineral or inorganic substances, must be obtained from the soil and brought to the roots **clearly** and **completely** dissolved in water.

CHAPTER IX.

EXPERIMENT WITH WATER CULTURE OF PLANTS.

IN order to make the experiment of growing a plant to perfect maturity, without being planted in the soil, take a wide-mouthed bottle, capable of holding one or two quarts. It must be fitted with a cork, and a hole

made in the centre of the cork, say half an inch in diameter, and an opening cut from it to the circumference, so that the plant may be glided out and in easily when required. You will next cover the bottle with stout paper, and top or neck with black sealing wax. It is a most important matter that **darkness** be secured, for plants feed through the roots best in the dark, as well as to prevent any fungoid growth within the dining-room of the plant.

We have next to see to the preparation of the bill of fare, and there are many of such bills. We shall select the following one, as suitable for the purpose, which has been successfully used by a celebrated English chemist:

Take finely powdered **burnt bone** (three hundred grains), put in a glass flask with water (pint), and to it **nitric acid** is cautiously added, so as to dissolve the bone, the flask being heated. After this has been done, a solution of **carbonate of potash** is added to the hot liquor, until it becomes slightly turbid. This represents the only troublesome portion of the cooking arrangements, for it now only needs the three following bodies to be added: Nitrate of potash, one hundred and seventy grains; crystallized sulphate of magnesia, one hundred and seven grains; and chloride of potassium, forty-six grains, with water sufficient to make it up to a quart.

We have thus prepared a very large supply of plant food; for although in its concentrated condition it only represents a quart, yet it will really give about ten gallons when properly diluted. When we are going to use the food for plants, we take about **two table-spoonsful**, and add it to a quart of distilled water, and mix in with it **one drop** of a strong solution of **perchloride of iron**. This weak and delicate liquid

now represents a very valuable plant food, and in this condition it is ready for use.

The seed having been sprouted in sand, the young plant is washed and then suspended in the hole of the cork, by the aid of cotton, wool, or other similar soft substance, with its roots reaching down to the water and its leaf in the air. Until a **green leaf** appears, **clean water** is supplied; but on the appearance of the green leaf, the cork and plant are removed from the bottle, the water is poured away, and the bottle filled with the properly diluted food.

When the growth of the plant is slow, there need not be any fresh supply of food for fully **fourteen days**; but in **hot weather**, when the growth is active, it is necessary to give fresh supplies every **seven days**. On these occasions the bottle is emptied and an entirely fresh supply of the diluted food is given. In this way you will produce a perfect plant **without putting it into the soil**.

The experiments which have been carried out go far to prove that plants take their supplies in a very **dilute form**, and yet these homeopathic quantities are really necessary. Take, for example, the one drop of iron solution added to a quart of water, being a ratio of about **one to twenty thousand**, and yet this minute supply was absolutely necessary. It was discovered by the same chemist that, when this iron was **omitted**, the young plant became **yellow and sickly**; but it quickly became **green**, and assumed a **luxuriant** growth, when this minute quantity of iron solution was added.

In the preparation of these watery solutions it is necessary to use distilled water if we want to arrive at accurate conclusions, because all natural supplies of water hold in solution more or less of the **materials** which plants require for food.

CHAPTER X.

HOW PLANTS FEED.

SPRING WATERS are sometimes sufficiently charged with the substances they have dissolved in their passage among rocks and soils, so as to be capable of **maintaining** the growth of plants. Rain-water is also more or less impregnated with matters taken from the air as it falls, so that it cannot be considered perfectly pure.

The lesson we may learn from these facts are, that plants take in their mineral food in an exceedingly dilute condition and in a **beautifully bright form**; likewise we learn that if they do not receive **all** the materials they require, they soon show that they have some want by presenting a sickly appearance, which will, ere long, result in a cessation of growth, and ultimately in untimely death.

Some experiments which have been carried out by these trials of water culture have led to the belief that **silica** is not always necessary to the growth of a plant; but it is safe to conclude, that all these substances found in a plant when **grown naturally** in a fertile soil, and which are constantly produced there in the highest perfection, are **desirable** for the plants. It will be always safest for us to accept the constant presence of substances found in the largest and best crops of any cultivated plant, as a sure indication that those substances are desirable for complete growth. It has been proved that many of these substances are absolutely necessary, and, as a matter of prudence, the farmer should regard a **complete supply** as being needful, and make provision accordingly.

In the right and proper use of these researches, made in the growth of plants by the aid of these solutions of substances found in them, a valuable lesson is learned, which may be profitably utilized by all cultivators of the soil. The delicate and clean character of the food received by the plants, and the bright and transparent stream of water which conveys the food into the roots, indicate some great changes taking place in the soil; when, for example, farm-yard manure has been used upon the land, the most offensive materials are often applied, and wisely so, too; but the plant **does not feed** upon them until, by changes carried on in the soil, they are passed into the circulation in a condition as **bright, clean, and odorless** as the water which sparkles in the goblets on our dining-tables.

CHAPTER XI.

✓ THE SOIL AND ITS CHARACTERS.

OF the three sources of plant food, viz., air, water, and soil, the soil requires from the farmer the **most attention**, and may be said to be the only one under his control; because air and rain-water can generally be obtained by plants without aid from man, and are the same quality and contain the same properties all over the earth, while soils differ greatly, containing in some places **little plant food**, and in others the **greatest fertility**.

The cultivation of the soil is now considered by all intelligent men as a **manufacturing** business of the highest importance to the welfare of nations.

Farm **experience** may justly be recognized as the **rudder** which controls the course of the agricultural

vessel, and we may also very properly regard **agricultural science** as the farmer's **compass and chart**, directing his vessel to the desired port. These, when skillfully used, become of infinite value to the farmer. It would be as foolish for the farmer to reject the help of agricultural science as it would be for the mariner to throw the compass and chart overboard; and, on the other hand, it would be as perfectly unreasonable for agricultural science to ignore farm experience as it would be in the mariner to unship his rudder and send it adrift. Of what avail would chart and compass be if the rudder (farm experience) be ignored.

We have spoken of the cultivation of the soil as a manufacturing business; the soil, therefore, we must regard as the **raw material** from which the cultivators have to produce the goods which are in demand, possessing those **qualities** necessary to bring the highest price in the market.

Other manufacturers, who produce goods from raw material, such as wool, cotton, timber, iron, or clay, bring to their aid every appliance that scientific investigation has discovered, with a view to economy in labor and the making of the very best fabric capable of being produced from the material used. It must be clearly evident that those who are to make the cultivation of the soil their business should have a thorough knowledge of the particular soil which they have to cultivate. Every farmer must bring science and skill to his aid if he may hope to draw from his land **the largest amount of produce, of the greatest value and lowest cost**, and at the same time keep his land up to the **highest state of fertility**.

The soil is generally regarded as merely earthly matter, devoid of all interest, except as a plant-growing source. If we observe closely, and form an

acquaintance with our soils, we very soon detect evidences of **character**, which closely approximates **animated existence**, such as **tempers, wills, and dispositions**.

The farmer's success frequently turns upon his familiar acquaintance with these points of character, yet few stop to inquire into the causes of these variations; but when the inquiring farmer traces out these variations, thereby becoming more intimate with them, the soil becomes interesting, and seems to become **invested** with new attributes of life.

Often have we been delighted and instructed by the conversation of the farmers who were the originators of the Randolph County Agricultural Society, in Illinois—men who had spent their agricultural apprenticeship in the pluvial climate of Scotland—while talking of their farm practice, each applying to his different fields **distinct characters**, as if they were living realities. One had a field that was always **hungry**; another a field that was **sick** and needed rest; another had one that was always grateful, responding kindly for the labor given; another had one that was **thin-skinned** and **shy**; another had one that was **stiff** and **stubborn**; another had one that was **sour** and **sulky** and never **kindly**, etc. Each had tried his particular experiment for each peculiar character, keenly watching **effects** and searching for **causes**. It is not to be wondered at that these men succeeded in making an ample competence, as all cultivators of the soil are sure to do who take the same lively interest in their land, and become familiar with its character.

CHAPTER XII.

GEOLOGICAL INFLUENCE ON SOIL AND NATIONAL CHARACTER.

THE soil has a history as well as a character, extending over vast periods of time, and has seen many ups and downs; indeed its history gives us a series of incidents of thrilling interest, and, to contemplation, a subject full of wonders and an endless, awe-inspiring theme.

The history of the human race records the **rise** and **decline** of nations and the **progressive** development of man's mental faculties; that of the soil, the gradual **evolution** of that part of creation which made it possible for the inhabitants of the world to attain their present physical condition.

Had the exterior crust of the earth been subject to no **modifying causes** since its first formation, there would have been **no soil** on its surface. There has been, however, a continuous series of changes going on, occasioned by the untiring and incessant operations of the various **forces in nature**, such as the rending of the earthquake, the upheaving of the volcano, and the **universal operations** of chemical and electrical agencies.

We find, by the testimony of the rocks, the record of the **progressive work of creation**, and the study of geology unfolds to the mind the indubitable proof of a design infinitely more provident and far-reaching than is possible for the highest human intelligence to fully comprehend or realize.

The history of the rise and decline of nations cannot be fully understood by any one who is ignorant of the long chain of events which had transpired, and slowly, but inevitably, **prepared** the conditions which **surrounded** them, without any act or design of theirs, and which **controlled** them to an extent which was entirely overlooked by them.

The controlling influence of the **distant past** can be no longer ignored. We must recognize how the physical condition of the earth's structure has influenced political boundaries, and how the rise and fall of great empires, as well as their civilization and mental development, have been the unavoidable results of geological causes.

A chain of geological events has shaped the **destiny of the people** of the United States to take the **front rank** of the great nations of the earth, both **morally, mentally, and physically**; with a capability of surpassing those of the Old World, in proportion to its **richer soil, vast mineral deposits, and more extensive domain.**

Whatever the future may have in store for the American nation, it may be set down as an incontrovertible fact, that its destiny was part of the **plan of creation**, when its foundation was laid in primeval and lifeless seas: that built it up layer by layer with all the **elements of wealth and power**; enriching it at one time with valuable **metalliferous** deposits; at another period with **lime or marble**; at another with **coal**; and at another with **stratified rocks**; that raised mountains to give **variety** to its scenery and climate; that denuded the mountain peaks and cold uplands atom by atom to furnish a **fertile soil** in a hospitable climate for the agriculturist; and that caused the great rivers to flow in the fruitful valleys to furnish highways for travel and commerce.

Creation to the geologist no longer means but a single act of **illimitable power**. It gives him a **grander** and **sublimier** view. The testimony of the rocks, when **rightly interpreted**, gives him evidence of a creation that is continuous, unfolding a design that is as illimitable in its origin as its final consummation transcends all human speculation. In short, geology reveals to man the Great Designer as a Being **infinite** in **knowledge, wisdom, power, justice, goodness, and truth**.

CHAPTER XIII.

HISTORY OF THE SOIL AND WHENCE DERIVED.

THE knowledge of the character and history of the soil will give the farmer instruction which he may utilize **with great advantage**, as the same **forces** are operating now as then which **did the work**.

We have now come to that part where the questions naturally present themselves: From whence came the first soil? How was it formed? It will now be our task to answer these questions plainly and clearly.

Soil is the result of the breaking down of rocks, with only one exception, that formed by vegetation, and commonly known as peat. All over the world a **continual change** is going on by which the whole surface of the land is being gradually washed down **into the valleys**, or deposited along the **level banks** of rivers, or in **lakes**, or finally washed quite down **into the seas**.

The wearing down of the stone work of our buildings fairly represents the mode in which rocks decay, and thus the **fine mealy, earthy matter** is produced

which constitutes the soil. Through long geological periods, which human investigation cannot name **by figures**, with any pretension to accuracy, this decay of the rocky surface has been going on without intermission, and **is still going on**, so that we have now an abundance of this earthy matter all over the face of the globe, amply sufficient for the wants of mankind.

Geology further informs us that at one time, very far back in the world's history, the surface of the earth consisted **only of rocks**, which are called primitive rocks. There are large masses of these **still remaining**, which enable us to know exactly their nature and character. The surfaces of these rocks were **pulverized by the gases existing in the air**, just as they are pulverized now—which was the first soil upon this world's surface. Since then a **series** of changes have taken place, which geology reveals to us in part. It tells us that that first soil has been formed **again into rocks**, which **again** were reduced to soil, and again turned into rocks, and these changes have been taking place **over and over again**, as proved by the various geological formations.

In the age in which **one kind** of primitive rock was soil, portions of that soil intermingled with portions from **different primitive rocks**, and in this manner soils have been **modified** in character; and these again have been greatly changed in their physical condition by **animal and vegetable life**.

So you see the soil of the field has a descent and an antiquity very extraordinary and wonderful indeed, and full of instruction, especially to the cultivators of it.

Now, as these reconstructions took place in this manner, we should find in the primitive rocks the **identical materials** which we have in the soils of our fields, as these primitive rocks were the magazines

from which all the supplies were obtained, and the various rocks, which were formed at later periods, are but reconstructions of the original materials.

✓ CHAPTER XIV.

CONSTITUENTS OF PRIMITIVE ROCKS AND HOW BROKEN TO SOIL,

PRIMITIVE rocks consist of **three** tolerably distinct groups, and are named by geologists as **granite**, **syenite**, and **trap**; and by analyses are found to contain the following materials:

	GRANITE.	SYENITE.	TRAP.
Silica	72.	59.8	43
Alumina.....	16.	16.8	14
Ferrous Oxide.....	1.5	7.	15.3
Lime.....	1.5	4.5	12.1
Magnesia .....	.5	2.6	9.1
Potash.....	6.	6.6	1.3
Soda.....	2.5	1.3	3.9
Phosphoric Acid, Sulphur, and Man- ganese	Traces.	Traces.	Traces.
Moisture.....	None.	1.4	1.3
	100.	100.	100.

The composition of the original earthy matter, you will perceive, varied a good deal in character, and, accordingly, by the **mixing** of these materials, the character of the reconstructed rocks was affected; likewise **marked variations in the soils**, which were finally produced, are to be found and thus accounted for.

It will be well now to notice how the **crumbling of rocks** is accomplished. The agencies are easily understood, and are at work **now**. It is very important that

the farmer should **know these agencies**, as they are, even at the present time, his valuable friends and helpers. Every person has noticed the beautiful, **bright polish** of the mould-board of a plough after it has been at work for a time, particularly in sandy soil. When it is left in the field for a day or two, the beautiful polish becomes **dim with rust**. This rust is caused by the action of the air on the iron. Chemists investigated the matter, and solved the mystery, and discovered the depredators. They find it to be a very busy body, known to us by the name of **Oxygen**, who is at the bottom of the mischief; they also discovered a companion of his, who is an able helper, and is known to us by the name of **Carbonic Acid**. These two companions are as **invisible as air**, and are called gases. They not only attack iron, but they operate on rocks; it makes no difference to them how hard and tough they be. Now rub the rust off the mould-board and examine it carefully; notice what a fine powder it is; this shows how powerful the operators are who did the work. The red rust contains **iron**, which **was taken from the mould-board** by these two agencies. Had the greatest force known to human skill been exerted on this metal, it could not have so completely **powdered** it as these two gases have done, without noise and almost without observation. Now, you will not be astonished when we tell you that they are equally mighty in pulverizing the hard granite.

CHAPTER XV.

AGENCIES WHICH REDUCE ROCKS TO SOIL.

THE action of **water**, and the change of **temperature**, work also together in pulverizing the hard rock.

These agencies, by being combined, their power to break down is amazingly increased. To demonstrate clearly to your mind the processes by which all these agencies **do their work** so minutely, so completely, and with a power beyond any resistance, we propose to take a piece of granite, and watch, and record the process. It will be necessary, in order to give the workmen a fair chance to show their powers, that we allow them an opportunity to reach it, and all that is necessary is simply to bring it **to the surface**. The instant it is there the workmen begin the **attack on all sides**. If you will examine the table given in a former page you will see that granite, with all its density and hardness, contains **two elements** within itself which cannot withstand the agencies existing in the air. These two elements are **iron** and **potash**, and are generally known. The oxygen and carbonic acid immediately begin their work on the iron and potash, and, after a time, we see a **rusty** mark on the surface of the granite. You may easily verify this fact by visiting a cemetery in which there is a granite monument of a few years standing. After the work has gone on for years we find small holes in the granite. These agents, like miners, have been driving "headings," and working out "rooms," and sending off what they have mined, thereby making the granite ready for the operations of the other two agents, water and temperature. The water penetrates the openings made by the "powers of the air;" then frost comes. You remember what he did with the pitcher filled with water when he went forth one frosty night—so he does with the granite pitchers; because water possesses the quality of **growing bigger when it freezes**, and bursts the walls enclosing it. The little fragments are held there till a thaw comes, when they are washed down from

their former position; the openings are thus enlarged, making room for a greater number of the airy workmen; and thus the work goes on with redoubled capacity and with energy untiring. No resting with these miners to take a smoke, or retiring from the work to take refreshments.

CHAPTER XVI.

HOW ROCKS ARE CRUMBLED WHICH HAVE NO IRON MATTER IN THEM.

You may say, "Now I understand how oxygen and carbonic acid, assisted by frost and water, are enabled to break down and pulverize granite and similar first rocks, but I cannot see how they can effect a like result with rocks in which there is **no iron to enter into an alliance** with them to accomplish the work of demolition, no traitor in the camp, if we be allowed the expression." We know of no rock besides fire-clay rock which, when blasted in the mine, is nearly as hard as whinstone, that is so free from iron particles. This rock is valuable just in proportion as it is free from all iron matter, consequently the atmospheric agencies have not an opportunity of entering into an alliance with their old colleague—iron.

Having long heard of the Mt. Savage fire-brick, so greatly famed for its ability to endure intense heat in furnaces without crumbling or fluxing, which it could not do if even an appreciable quantity of iron were present, upon a late occasion we visited the mines from which the "clay" is obtained for the purpose of testing this very subject. By the kindness of Mr. Findlay, foreman of mines, we were taken a long distance under ground, entering the opening in the side

of the mountain in a tram-way car, the tram-way running nearly horizontal to the "face" of the rock, where the miners, with drill and sledge, were diligently making holes in which to put powder to blow it out from its ancient bed, where it had been sleeping quietly for so many ages. The sharp chinking sound made by the steel drill and sledge, gave testimony to the hardness of the rock. We examined the fine dust taken from the drilled hole, and, rubbing it between the thumb and finger, easily detected its **fragmentary** condition, by its fine gritty feeling. We were there shown a stratum of rock, which was so free from any trace of iron as to be pronounced by the chemists "pure fire-clay rock." We procured a specimen from this stratum, and, after submitting it to the **rains** and the **frosts** for about two months, it was completely reduced to atoms; on testing it between the thumb and finger, it felt as smooth and fine as the particles composing grease. There was no fragment, no grit—the demolition was complete.

Although no ferreous matter was present to join in conspiracy with the oxygen and carbonic acid of the air, yet water found **an entrance**, and permeated the specimen entirely, which we had taken for a test; and as water **will not be restrained** from growing bigger when it freezes, so the water in the specimen froze, and, in its effort to grow bigger, separated the rock particle by particle.

We also visited the brick works of the same company in the village of Mt. Savage, Md., to examine the rock-crushing process. Mr. Clifford, foreman of the works, very kindly showed and explained the operation. The rock is subjected to the crushing force of an iron roller of immense weight. When it is of sufficient fineness it falls through a sifter into a receptacle below, and taken

from there by an elevator, and passed on to undergo the operations of mixing with water, moulding, drying, and burning. So complete, apparently, is the rock broken down, that the clothes of the men attending the crusher are as white as those of a miller; yet when that which was brought up by the elevator was examined, it was found to be chiefly fragmentary.

In the contemplation of this work we cannot refrain from exclaiming: Man's works, how powerful they are! But they fade into insignificance when contrasted with the complete and perfect work of the quiet operators appointed to do the will of the Great Designer.

CHAPTER XVII.

THE BREAKING-DOWN OF ROCKS TO SOIL.

SOME may think that this breaking down of the primitive rocks could only take place to a very limited extent; but if we reflect for a moment and bring before our mind the time when "dry land" first appeared, and there was no soil, and think of the **immeasurable surface** presented to the air agencies, and the vastly greater quantity of carbonic acid in the air **then than now**, together with the other agencies, water and temperature, we shall understand, in a measure, how **illimitable the power was**. The work went on **much more rapidly** with the secondary rocks and later formations, they being much softer; and, as the work of demolition went on, the rocks got covered more and more, and presented less and less surface to the air, and were placed beyond the influence of all the pulverizing agencies; thus the work of breaking down gradually decreased, and finally stopped, till again thrown up into the air.

As soon as there was **sufficient soil** made for "man to till and dress it," and employ his **skill and knowledge** in the production of food, and **all things necessary for his comfort**, the reduction of rocks gradually diminished because the work was sufficiently advanced to meet the necessity of the case. It now remains with the intelligence and skill of the farmer "to make the soil fruitful and bring forth abundantly."

We may mention another agency which helps to break and pulverize some kinds of hard rocks. If a piece of polished marble be covered with clean sand, and a few seeds of mustard, or other seeds, be placed in it, and then put in a moist, warm atmosphere, the seeds will soon germinate; after allowing the young plant to grow for a short time, and then clean everything from the marble, minute holes will be found in it, which were made by the acid sap of the young roots eating into it to obtain food.

The roots of trees, too, entering crevices of rocks, frequently split off great blocks as they expand in thickness; even paving-stones have been known to be broken by the growth of tree roots under them.

The broken and powdered rocks formed in these various ways are washed down the slopes of the mountains by rains into the rivers; in many flat plains the rivers overflow frequently, and spread their material over the land. In this case we see a sorting and distributing action taking place. When a river rushes down as a torrent it carries with it mud, sand, gravel, and even large stones. But when the descent becomes less, so does the swiftness of the current, and the large stones are first dropped, afterward the gravel, then the sand, and, lastly, the fine mud is distributed over the plain, and only deposited where the current has almost

or quite ceased. In this way beds of gravel, sand, and clay are formed, thus producing soils differing from each other. Great quantities of the same materials have been carried into the sea, and apparently lost; but beds which were formed in that way, many ages ago, have been since lifted up by **earthquakes** or other **movements** equally powerful, and from these beds many of our soils are formed.

When we recognize the power of nature's forces existing in the air, including temperature and moisture; the action of the roots of plants themselves; the **tread** of animals; the **rushing rivers** causing rocks to grind each other; the **glaciers**, these ice-rivers fed by the ever-accumulating snow, descending mountain gorges, with slow but irresistible force, smoothing, grinding, and striating the rocks in their way; the **volcano**, throwing out the molten lava and ashes; and the **icebergs** of the glacial period, which, when the land was being **elevated** by some internal force, were arrested in their course, and descended the mountain sides, smoothing hills and valleys among which they passed, and finally melting and leaving their *debris*, as mounds of sand, gravel, or boulders; all these gave their contribution; and the varied particles thus intermingling, the formation of **the different classes** of soils ceases any longer to be a subject of wonder.

CHAPTER XVIII.

THE PHYSICAL COMPOSITION OF SOILS.

WE have now learned that some soils have been carried a long distance **from the place** where they were formed, and may, therefore, be very different from

the **rocks underlying them**, while others have been more quietly spread out by the rain upon and **among** the rocks from which they are derived. These are called native or local soils (soils in *situ*); the former are said to be **transported soils**.

The **great variation** in character renders it necessary that we should be able **to distinguish soils**, so that we may be able to describe them with some degree of accuracy. For this purpose **sand and clay** have been selected for the sake of **contrast**, to enable us to divide them into **two distinct groups**.

In the sand on the seashore we have the one in perfection; and in the clays used for pottery we have the best specimen of the other. The one, when it is mixed with water in a vessel, falls to the bottom rapidly; the other, when it is mixed with water, falls to the bottom slowly, rendering the water muddy for a considerable length of time. There are other marked differences in their character; for example, sand, when it is wet, is hard to the touch; it has little cohesion; it cannot be formed by the hand into any definite shape; it is gritty; it allows water to pass through it rapidly, and is firm to the foot. Clay, on the other hand, when it is wet, is the direct opposite in all these respects; it is soft to the touch; it has great cohesion; it can be moulded into any definite shape; it is soft and smooth; it holds water upon its surface, and is slippery to the foot.

If a soil consists of more than three-fourths sand, it is called a sandy soil; if, on the other hand, more than three-fourths of its weight is clay, it is called a clay soil. A mixture of about half sand and half clay, it is called a loam. If there is rather more than half sand, it is called a sandy loam; if rather more than half clay, it is called a clay loam. All these soils may have

a small quantity of lime and vegetable matter, making them "rich." A soil which contains nearly a quarter of its weight of lime, is called a marl; if the rest of the soil is mostly sand, it is called a sandy marl; if mostly clay, it is a clay marl. Soils which contain a large quantity of lime are calcareous soils. A soil which contains a large portion of vegetable matter, is called a peaty soil. These differences among soils may be tabulated as follows:

Sandy Soils.....	{	Sand	$\frac{3}{4}$	sand to all sand.
		Sandy marl.....	$\frac{3}{4}$	sand to $\frac{1}{4}$ lime.
Clay Soils.	{	Clay.....	$\frac{3}{4}$	clay to all clay.
		Clay marl.....	$\frac{3}{4}$	clay to $\frac{1}{4}$ lime.
Loam Soils.....	{	Sandy loam.....	$\frac{1}{2}$	sand to $\frac{1}{2}$ clay.
		Clay loam.....	$\frac{2}{3}$	clay to $\frac{1}{3}$ sand.
		Sandy loam.....	$\frac{2}{3}$	sand to $\frac{1}{3}$ clay.
		Calcareous soil.....	$\frac{1}{4}$	lime to all lime.
		Peaty soil.....	$\frac{1}{4}$	humus to all humus.

Each of these soils can be again divided into poor, middling, and rich, or fertile, according to the quantity of the other matters contained in it. Thus, a loamy soil, containing **lime** and **vegetable matter**, as well as sand and clay, is richer than one containing sand and clay only; and, generally speaking, the most fertile soils—that is, those yielding the greatest amount of plant food—are those which are composed of **a fair mixture** of all the **four constituents**.

A cubic foot of dry sand weighs about one hundred and ten pounds, while the same bulk of dry clay weighs only about seventy-five pounds; yet a farmer calls a sandy soil **light**, and a clay soil **heavy**. His judgment is based upon the ease or difficulty of working the soil **more than the actual weight**. The particles of sand are comparatively large, with no tendency to stick together, or to the implements with which it is worked, so that a plough easily moves between the

grains; and the soil is called light because it makes light work. In a clay soil, however, the particles are so fine, and have such a tendency to stick to one another, and to the implements passing between them, that much difficulty is experienced in moving and separating them; this is heavy work; therefore, this kind of soil is said to be heavy.

CHAPTER XIX.

CAPILLARY ATTRACTION AS AFFECTED BY THE PHYSICAL CONDITION OF THE SOIL.

THE power of holding moisture by the soil is another important subject for the farmer, which we will now briefly investigate. If one end of a fine glass tube be dipped in water, the water rises in it; and the finer the tube the higher above the surface the water rises. This is called **capillary attraction**, because of the hair-like fineness of the tube. The same action takes place wherever there are small spaces between substances, as in a sponge, the wick of a lamp, or a lump of sugar—all of which have the power of drawing and holding water in the little spaces they contain. This is a very important property in soils. The water in a saucer under a flower-pot containing soil is taken up in this way, rising up to a **greater height** if the spaces are small, and to a **less height** if the spaces are large, and **staying there** without falling back. In coarse sand it would not rise far; but in clay, where the particles are finer and closer, the capillary attraction is greater, and the water rises much higher.

Now suppose one hundred pounds of dry sand to be placed in a vessel, with holes in the bottom, it will be

found to receive and hold twenty-five pounds of water before it begins to drop; then fill it with the same quantity of loam, and it will be found to hold forty pounds; if filled with clay loam, it will hold fifty pounds; and if filled with clay, it will be found to hold seventy pounds of water before beginning to drop. **Clay soils** likewise absorb more moisture from the atmosphere than sandy soils. If one hundred pounds of sand be spread out when the atmosphere is moist, but rainless, for twelve hours in the night, it will absorb only a few ounces of water; if clay loam, two and a-half pounds; and if clay, nearly four pounds of water.

The influence of capillary attraction is beneficially felt during the period of the growth of plants. However well a soil may be supplied with the food required for a crop, plants only can make use of it in a **liquid form**; the presence of water to carry the food into the circulation is **just as necessary** as having the food there. During the summer months, when the sun's rays are shining strongly upon vegetation, large quantities of water are needed, and it is at such times that this system of attraction proves its utility, by bringing up to the roots refreshing supplies of water, finely divided, **like a diffused mist** in the soil, which enables the growth to push on luxuriantly.

But it may reasonably be asked by some, who may think of drainage in this connection: What is the use of **draining water** from the soil if it be carried back by this capillary attraction? We shall try to give you light on that subject in another chapter; but, in the meantime, we shall ask you to reflect, and find out the reason for the flower-pot having a **hole in the bottom**, and what would be the consequence if no hole was there.

CHAPTER XX.

PHYSICAL CONDITION OF THE SOIL.

THE influence of the mechanical or physical condition of the soil is a subject fraught with the greatest importance to the agriculturist. We may take it for granted that all acknowledge the need of air, warmth, and moisture to enable a plant to grow. In order that the seeds may have air, a **loose condition** of the soil is necessary. For this condition sand is better than clay, because the spaces between the grains are larger, and thus allow the air to enter. But if these spaces are too large, there cannot be enough of water retained in the soil, and the young plant will consequently suffer for want of moisture. Again, if too much moisture is retained in the soil, it not only shuts out the air, but it becomes cold, and deprives the plant of warmth, thus preventing the plant from receiving the second requisite necessary for its growth. From these facts we are forced to the conclusion that the best kind of soil, in regard to its physical condition, for a seed-bed, is a mixture of sand and clay—that is, a loam, not so close and fine in its grains as to prevent the free access of air and warmth, and not so open as sand, allowing the water to run through it too quickly, or having little power of capillary attraction.

We may now conclude this subject of the physical condition of soils by briefly referring to the other two agencies that have contributed matter found in our agricultural soils. In all cultivated soils you will observe a **black substance** intermingled with the

mineral matters; it is generally known by the name of "vegetable mold" or "humus;" this is contributed chiefly by the air and the sea.

It will be learned from the above that the physical condition of soils is entirely due to the proportions in which sand, clay, lime, vegetable matter, and mineral fragments enter into their composition.

CHAPTER XXI.

CHEMICAL ANALYSES OF SOILS.

THERE is another section of the work which treats of the composition of the soils, and this shows us what bodies are found in them, in what proportion, and in what conditions of **solubility**. These are determined by **chemical analysis**, which is very difficult even for professional chemists to do. It is generally looked upon as something which may be easily done, but it is one of the most complicated and troublesome analysis which has to be carried out.

The information thus to be obtained is of immense value to the farmer, provided it be carried out in **an exact, correct, and proper manner**. Among the first things we learn by this examination of the soil is, that a very small portion of the best soils is really ready with food for the **immediate use of plants**. That which is ready for immediate service is called the **active portion** of the soil, whilst the remaining store is known as the **dormant** or sleeping portion.

Here then we get our first chemical division of the soil, viz.: The **active matter** and the **dormant matter**. The dormant matter is only sleeping, and while in that condition it is valueless, yet it is really of great value. It awaits the intelligent farmer to arouse

it from sleep, when it will become as the reserve forces of an army, to be called to duty when the active forces are becoming exhausted. It would be imprudent to allow those on active duty to be completely exhausted before calling up the reserves; but on very many farms the reserves are **never called up**, and the land in consequence is completely worn out and exhausted, while yet containing a vast amount of fertile matter, which has been permitted to remain in peaceful slumber in the soil.

The chemical analyses of soils have been very generally carried out, as if **all** the fertilizing matters present in them were at the service of the growing crops. It was thought that if a farmer knew what his crop wanted, and also what he had in the soil, it would be an easy matter to supply the wants by a **manure** containing the **particular ingredients needed**.

In that hope he was bitterly disappointed, because the analysts disregarded the well known fact above mentioned, and analyzed the soil as if the active and dormant matters were in the same condition, and were all ready for the use of plants.

If a farmer is to be benefited by an analysis of his soil he must know what **he has there that is available for his crops**; there must be a **distinct line drawn** between the **active** and **dormant** portions of the soil; then he may get information which will be valuable for his guidance.



CHAPTER XXII.

AGRICULTURAL CHEMISTRY—NECESSITY FOR DEEP PLOWING.

You have been shown that plants require a great variety of different kinds of food for their full and

perfect growth. Not one of these bodies is available as plant food, unless it is in such a condition as to be easily dissolved in water, aided by some organic acid. Thus water, aided by a weak acid, is the vehicle by which the food passes from the soil into the plant. **Solid matter** which will not dissolve in such water may be useful mechanically in giving an abode to the plant, but **cannot enter** its organism.

It is of the utmost importance to the farmer to inform himself as to the **possibility** of making the dormant matter take the active form. This is quite possible, and under **good cultivation** it does take place to a large extent. The friendly helpers are the atmospheric agencies, which were so effective in breaking down the rocks into soil.

Having increased the amount of surface soil by **deep cultivation**, we find the rain water carrying its supply of oxygen and carbonic acid, persistently bringing plant food into solution, and passing it over to the safe custody of the **silicates in the soil**. In this way large quantities of insoluble matter are brought into an active state, and in good soils we find it well and carefully preserved until the growing crops demand the supply. It must now be evident, that just in proportion to the extent that we allow these **atmospheric agencies** to act upon the soil and subsoil, so we shall the better enable them to change the dormant matter, with which it is permitted to mix, into a condition available for plant food. These agencies accomplish a work which is equivalent to the purchase of so much manure. It is, therefore, very desirable for the farmer to give them every opportunity for working in his interest.

The farmer can best facilitate this work by a **thoroughly good and timely cultivation** of the soil.

Let us compare, for the sake of making plain and clear, what we mean, **two fields** having similar soils—say heavy, clay soils, similarly located or side by side. In the one case, we will suppose the field has been deeply plowed **in the fall**, and laid up as roughly as possible, so as to expose as much surface as may be attainable to the action of the sun and air. In the other case, the plowing has been postponed **till spring**. In the one case, we will see that the friendly helpers have been at work, promoting the change of any sour matter, converting it into wholesome plant food, bringing some of the dormant matter into an active form, and making the soil loose and friable—these being all favorable to the growth of vegetation. All this has been done by the action of the oxygen and carbonic acid in the air, assisted by water and temperature. In the second case, no effort was made to let these agencies bring about the same changes; but, as the soil lay in its solid bed, and probably water-soaked, it was really becoming less fit for plant growth. In the one case, the land was plowed up in the spring tough and sour, requiring **more labor** than the other; yet it was not brought into such a productive condition. In the other case, we have a luxuriant growth of crops, at a smaller expenditure of work; while in the other case we have the work of nature's agencies rejected, and the result is far from gratifying and very expensive.

It is well that we should value highly these friendly helpers, and that we should do all we can to give them the best opportunity to do their work. The advice of the old farmer is directly to the point: "Marry the air and the soil, my son, for unless they be allowed to **intermingle and join with each other freely**, the soil will not bear abundantly."

CHAPTER XXIII.

DRAINAGE A MEANS OF GETTING AIR INTO THE SOIL.

THE drainage of the land is another means adopted to admit the atmosphere to the soil. The common idea, that land is drained simply **to remove water**, is too limited; it does a great deal more. The first effect we see, of course, is the running away of the water; but water would not flow away if air is **not admitted**. This may be easily proven by the tapping of a barrel of cider, or any other liquid, near the bottom; in order to draw it, a hole must be made at the top of the vessel into which the air **will rush** as long as the liquid **flows**.

The drains, therefore, allow the water to run away, because **they can draw air into the soil**; consequently we drain land as much for getting air into the land as for taking water out. The benefit arising to the soil is apparent; for wherever air is admitted, its oxygen and carbonic acid immediately commence work, and go silently on day and night, changing the dormant matter in the soil to its active form.

The farmer who treats his land to thoroughly good cultivation and drainage, will be amply rewarded with the rapidly improved fertility of the soil. **Subsoiling** the land produces the same condition, by stirring up the soil which lies beneath. This is a means whereby the passage of water through the soil is rendered more easy, which is followed by the air, and, as a consequence, more of the soil comes under its influence, provided,

always, that the great agricultural flower-pot has a hole in the bottom.

Another advantage arising from the passage of the air is, that it **sweetens** the soil by changing the **sour** and unhealthy **decaying vegetable matter** in it, to the higher form of **carbonic acid**, which is one of the farmer's friends. The yellow oxide of iron, which is a poison to plants, becomes, by the action of the oxygen in the air, another helping friend to the farmer.

In addition to all these, there is yet another servant ready to aid him, and that is the **ammonia** in the air. This is a very expensive substance to purchase; yet it **exists** in the air, and a very considerable supply can be gathered from it by the soil, if it is properly **aerated**.

Now, you will see that there are many servants waiting to help the farmer to make his land more fertile, if he will but receive their ever ready and willing assistance. These ask no wages; they require no rest; but day and night they are ready to work if they are permitted to do it. **Water-soaked land repels** all these friendly helpers, as well as solidified land.

CHAPTER XXIV.

THE ACTION OF HEAT AND OTHER ADVANTAGES OF DRAINAGE.

IN order to understand the beneficial effects of drainage more clearly, we shall investigate the laws governing the **action of heat**, because we may not be able to

grasp the ideas satisfactorily unless we start with a knowledge of **first principles**.

Substances that are warmer than their surroundings, communicate their excess of heat in three distinct ways: (1) By conduction. (2) By convection. (3) By radiation.

To demonstrate the **conduction of heat**, hold one end of a brass wire between the thumb and finger, and the other end in the flame of a lamp; the experiment will terminate suddenly. Now take a piece of dry wood the same size, and hold it in the flame; it will become red hot and blaze without burning the fingers. The heat is led along the brass wire; it makes no difference whether it be held to the flame **upwards, downwards, or sideways**; the wire is, therefore, said to be a good **conductor**, and wood a bad conductor.

The conducting power of different substances varies considerably. **Metals** are good conductors. **Silver** is recognized as the **best** conductor, **water** the **lowest**, and **clay** the **next**. The ratio of their conducting power may be stated thus: Silver, 1,000; water, 1; clay, 4.

Convection is the **conveying** of heat by the **air, gases, or liquids**. The common notion, that heat **ascends**, is based upon the action of heat by convection. Water, as we have stated above, is one of the very poorest conductors of heat; yet we all know that heat is transmitted through it, as when we boil water in a pot. If, however, we placed water in a **fire-clay pot**, and apply the heat **to the top**, which is the way heat is applied **to the soil**, that "waited-on pot" would be long in boiling. The **upper film** of water receiving the heat would remain **lighter** than the rest,

and **retain** its position; and, being a poor conductor of heat, it parts slowly with its heat to the water beneath, which **remains cold**. Its warmth is not increased very much by the pot, because its material is also a poor conductor. When the heat is applied to the bottom of an **iron pot**, the hot metal of the pot heats the **bottom film** of water by **direct contact**; this film expands, becomes lighter, and rises through the water above it, **warming it by contact**, and speedily causing the "pot to boil."

Radiation is a flinging off of heat in every direction. Bright, shining surfaces are profligate radiators and poor absorbers of rays of heat; they, therefore, **cool quickly**. The soil is one of the best absorbers of heat when it is drained of superfluous water; but if, however, stagnant water has to be evaporated from it, the heat is **carried away** and the soil remains **cold**.

That evaporation has a cooling influence, you may easily prove to your own satisfaction by wetting your **finger** with water in a **warm** room and hold it up; you will feel the **cooling** influence; if made wet with **spirits**, the evaporation will be **more rapid** and produce a **cooler** feeling; and if **ether** be used, which almost instantly evaporates, it will produce a **still cooler** feeling. Ice may be produced by evaporation, so great is its power of carrying away heat.

According to the natural laws governing the effect of heat on water, it **contracts** gradually in volume until its temperature is about thirty-nine degrees; **below this** it begins to **expand** until it reaches thirty-two degrees, when, under ordinary conditions, it becomes solid, and, in **doing so**, undergoes a **greater** expansion, **eight** volumes of water becoming about **nine** of ice.

The expansion of water below thirty-nine degrees has very **important results**. It prevents all our water supplies being frozen up. If water contracted **continuously** till it reached the **freezing point**, we should have all the water in our lakes reduced to that **temperature** before freezing commenced on the surface, and a very brief continuance of freezing weather would **solidify the whole mass**; but, as it is, the water at thirty-nine degrees, being **most dense**, **sinks** to the bottom and there **remains**; while the water at thirty-two degrees, being the **lightest**, remains on the **surface**, and ice, being a **bad conductor** of heat, preserves the **too rapid cooling** of the water beneath. We have, consequently, a gradual freezing of the surface downwards.

We understand now how a proper system of drainage favors the passage of water through the soil, and passes it away to some lower level. It will also be easily understood that the passage of **warm air** through the soil must, of necessity, raise its **temperature** by its heat being transferred to the land. This is a very constant source of heat during the months when the crops are in a very active state of growth, and is a means of making a **distribution of the heat** to a greater depth and more equally throughout the soil.

The warm rays of the sun falling on land soaked with stagnant water, or the warm breezes passing over it, **do not warm it**, as they would drier land. The stagnant water has to be made to pass away as a vapor before the warmth of the sun or the warm breezes can exert a stimulating influence on the soil. The cause of this will be easily understood when we remember what a quantity of heat is required to change water into vapor. The consequence is that **wet** and undrained

land is found to be cold and unproductive; the crops are always kept back in their growth, and are much later in coming to perfection than those grown upon drained land.

The attraction by the soil, where drainage keeps it comparatively dry, for the heated rays of the sun is proven to be very great. On the fallow the portion of the air coming in contact with the soil becomes expanded and struggles upward through the superincumbent cooler air in visible wavy lines.

The soil is also a slow radiator as well as a good absorber of heat. On this account the herbage on drained land is much less liable to be injured by spring frosts. This property enables it to keep up its temperature and prevents its being reduced to the freezing point for a considerable length of time. The power of the soil for absorbing a great quantity of heat and parting with it slowly has long been recognized by the farmer. When he takes a journey in his wagon or sleigh on a cold winter's day, he does not heat a block of iron or wood to keep his feet warm, because he is aware that, although he can warm these materials to a high degree, they would part with their heat so rapidly that their usefulness for heating purposes would soon be gone; but he takes a brick, which is simply soil compressed and burned, and heats it up to a high degree, then rolls it up in a piece of carpet, and his feet are kept comfortable for a long time, because the brick parts slowly with the heat stored up in it.

The following table is taken from Jamison's prize essay "On the Action of the Atmosphere in Newly Deepened Soil in Scotland," showing the increased temperature of the soil and subsoil, being

important as affecting vegetation, and likewise valuable because it is reliable and instructive on this subject:

TAKEN IN PERFECTLY FINE WEATHER.

	Mean Temperature.		Elevation of tem- perature by the sun's rays on a drained surface.
	Earth's Surface. Degrees.	Air in Shado. Degrees.	Degrees.
January	54.1	24.6	29.5
February.....	86.2	43.	43.2
March.....	99.5	46.6	52.9
April.....	121.6	61.7	59.9
May.....	131.2	67.3	63.9
June	139.8	75.2	64.6
July.....	146.3	81.3	65.
August.....	130.1	68.9	61.2
September	119.8	68.0	51.8
October.....	80.8	42.8	38.0
November.....	72.7	40.1	32.6
December.....	59.2	35.6	23.6

The beneficial effects of drainage for soils naturally water-soaked, need no further comment, and may be briefly summed up. The temperature of the soil is raised; porosity for moisture, though not for wet, increased; disintegration is affected, and nutritive soluble substances liberated; atmospheric gases absorbed; injurious substances changed so as to be positively beneficial to vegetation; and the wasteful surface flow from fertile fields reduced to the minimum.

CHAPTER XXV.

OBJECTIONS TO DRAINAGE, AND THEIR FALLACY.

OBJECTIONS have been made to underdrainage, which will now occupy our attention briefly: (1) It is urged that the water is **carried away** from the land **too**

quickly, causing the overflow of rivers. (2) Because it is not allowed to remain long enough on the land to percolate down through the soil to supply springs. If we reflect for a moment, we cannot fail to see how erroneous is the first objection; underdrainage increases greatly the capacity of the soil to hold water by giving it a larger area for distribution. A field which is underdrained, therefore, holds more water before reaching the point of saturation than a field of the same character can possibly do without being underdrained; hence, a less flow of water from the drained land in proportion to the amount of rain falling upon it than from the undrained land.

When the Ohio River overflowed its banks a few years ago, and wrought such great destruction, drainage was held responsible in a great degree; but when reflection had time to assume its sway, it was discovered that all the water flowing from tile drains into the river and its tributaries, would not have much more than filled a good sized mill-race. These, we consider, to be sufficient to dispose of the first objection; and as for the second, the groundlessness of it will be apparent when we remember how small the area which is, and always will remain, undrained by artificial means.

The clearing away of the forests, and the surface flow from undrained lands, may be set down, without fear of successful contradiction, as the chief causes of destructive floods, and, we may add, excessive droughts. Just in proportion to the protection of the earth's surface by trees from the sun's rays, so is the gradual melting of the winter's snows; without this protection, spring thaws are rapid, and torrents ensue.

The sun's rays in passing through the air **do not heat it**; the air is warmed **by radiation** from the **earth's surface**; and the greater the degree of heat which the air reaches, the greater is its capacity to hold moisture; therefore, if air be saturated with moisture to the point of precipitation, and afterward passes in summer over a **denuded surface**, it being greatly heated by radiation from the bare surface, its capacity to hold moisture is increased, and no longer remains at the point **of precipitation**, but passes away to descend as rain where the radiation is modified by **the forests** and the land **well covered by vegetation**. The farmers in the prairies will tell you mournfully, "that the showers, when most needed, take to the timber and follow the creeks." This is an observation frequently made by the prairie farmers.

Another important benefit is brought about by thorough drainage, which of itself is sufficient reward for all the labor and cost in the construction of drains, and that is the healthful and **salubrious condition of the atmosphere**. Where is the country which abounds with **malaria, bilious fevers, and agues**? It is not in the mountains where the land is drained by nature, and the sparkling waters gush forth from the drains of nature's own making, and the "living waters flow;" but all these ills of life prevail in the country where the land is **water-soaked**, having no hole in the bottom of the great agricultural flower-pot, and where water **stagnates in sloughs and ponds**.

The health of man, and beast, and herb, are all benefited by drainage.

The approved method of draining is: (1) Bore and dig the ground to ascertain the kind of soil to the depth of three or four feet, so as to know how far

apart the drains should be. (2) Take the necessary levels. (3) Lay off the lines of main and minor drains. (4) Make a map of the proposed work. To put straw, brush, or stones on the top of the tiles when placed in position in the drain, is bad practice. Fine earth should be closely packed on top of the tiles to cause the water to enter the drain **at the bottom**. The greater the quantity of soil that water has to percolate through before it enters the drain, the better is its opportunity **to pass over to the safekeeping of the double silicates** the plant food it holds in solution. Water from such drains, when caused to overflow a meadow that is itself well drained, will add little or no plant food to it.

This was at first doubted, and a case has been cited where a meadow was overflowed with water from the drains of a field on a higher elevation, which was sufficient to keep up the power of the meadow to produce good crops of hay without its receiving **any other fertilizer**; but upon investigation it was discovered that some of the drains tapped springs **at their source**, and conducted the water directly to the meadow, which gave up the plant food it held in solution to the soil it had to pass through. You will remember what we before told you that some kinds of bright, sparkling, spring water hold the elements of plant food in solution in sufficient quantity to fertilize the land through which it percolates. The springs in this case were enriched with the inorganic substances of plant food, and thus fertilized the soil, which accounted for **this drain water enriching the land**. The **surface flow** of water from a fertile field which spreads over another field well drained will carry an ample supply of fertilizing substances to it, which will make it yield abundantly; but water,

after percolating through a loam or clay loam soil into drains, is deprived of its fertilizing ingredients by the double silicates, and is thus rendered worthless as a source of plant food. The surface flow of water from cultivated fields is the **maximum of evils to American husbandry of the present day.**

CHAPTER XXVI.

ORGANIC CONSTITUENTS OF THE SOIL.

WE may now consider the organic constituents of the soil. The quantities existing in the soil differ considerably; but they are present in all good soils.

If a portion of soil be burnt on an iron plate, a smoke will be produced from it; and if weighed before and after burning, we will find that it has lost weight by the burning. The loss represents the **water dried out**, and the **organic matter burnt off**. If we examine the new soil produced by the atmospheric agencies from the rocks, we shall find very little organic matter in it, and in some cases none. The fact is, that only **the lower orders of vegetation** grow in it; but as these die, their remains mix with the soil in which they grew. After this has been going on for successive years, the soil becomes somewhat enriched by the remains, when it becomes fitted to produce plants of a higher order, and these add still more vegetable matter to the soil, so that it finally becomes mixed with a great deal of organic matter, which was produced upon its surface, and is thus prepared in a natural way for growing a crop.

The term **organic matter** is generally applied to those portions of the soil which at some time or other

have been organized, and have **performed functions of animal or vegetable life**. Organic matter consists chiefly of substances drawn from the air, and the carbonic acid is the chief contributor. As we carry on the ordinary processes of cultivation we increase the quantity of this organic matter. In fact, the **general tendency** of cultivation is in the direction of adding to the soil organic matter.

Some crops are especially valuable, because of the organic matter they add to the soil, such as **clover and green buckwheat**, when plowed under.

An ordinary observer, in looking at a grass sod, can see the numberless small roots with which the turf is so full, and the black color gives evidence to the experienced eye of earlier supplies of rootlets which had decayed in the land.

We shall now examine into the benefits which the soil derives from this organic matter: (1) It has a tendency to give a **freedom to the soil**, which enables the roots to penetrate it in search of food. Stiff clays which, from the extreme fineness of their particles, have a tendency to **become firm and compact**, are greatly benefited by the intermixture. In the case of **sands** it discharges an equally useful duty. In these soils there is no difficulty of the root penetrating the land; but there is a want of firmness, and in such cases the increase of organic matter is very valuable; in short, in every kind of soil the intermixture of organic matter is **beneficial**—excepting peaty soils, of course. (2) It increases the power of any soil for **absorbing moisture and gaseous matter** from the air. Nor must we overlook the fact that such organic matter is one of the means whereby manure and plant food are held in the soil, particularly sandy soils, when the previous condition of the land would

have allowed it to be washed away and gone beyond the roots of the plants.

It has become the practice with intelligent cultivators of the land, who have light soils having little power to hold the food in a soluble condition, to apply the farm-yard manure **to the young clover**, which encourages a strong, rich growth, and thus it **preserves** the greatest portion of the plant food, which would otherwise have been washed away from the soil. The great amount of rich clover roots which **decays gradually** during the growth of the following crop, yields up a large store of fertilizing matter, just as it is needed by the crop.

CHAPTER XXVII.

BAD CHARACTERS OF SOILS AND HOW TO REMEDY THEM.

WE may now consider the characters of soils, to which we alluded in a former chapter. This is very important, because these characters of fields indicate certain opinions of **intelligent practical farmers**. We shall endeavor to show what the farmer means by saying that a certain field has a **hungry soil**.

Because a particular field is always in want of nourishing materials, the farmer says of it that it is hungry. **Sands** and **gravels** belong to this class, because they have little or no power in holding the soluble portions of the manure. They are generally known by an absence of the double silicates and ferric oxide, as well as having a small supply of organic matter; soils also whose surface is liable to be washed or floated away by every heavy shower are always in need of a supply of manure.

The common mode of curing the disease in the sandy or gravelly soils is to **add clay** and encourage the

accumulation of humus in them; and to cure the washing away of the surface soil, **deep tillage** and **subsoil draining** will reduce the surface flow to a **minimum**. Just in proportion as these means are applied, so will the land cease to have that character applied to it.

Another class of soils is known as **tough** and **obstinate**. This class is found to contain a large quantity of clay; but in a majority of cases it displays these points of character when under **bad management**. When individuals or animals have such an unfortunate character, skill in treating them so as not to arouse the bad propensities **proves the master mind**; it is the same with the soil, because if treated with skill it will be rendered yielding and kindly. If a farmer unskilled in the management of a clay soil ploughs it in the **spring**, in preparation for a crop, it is likely to become **cloddy, tough, and obstinate**, and to need a great amount of labor to reduce it to a fitting condition for a good seed bed. If, on the other hand, such a soil had been well drained, and ploughed up in the fall, and exposed to the influences of air, water, and frost, we would see a **kindly, mellow soil**, in the very best condition for a seed bed. This condition is infinitely better and more complete than any state we could bring it to, by any amount of manual or horse labor, when treated to spring ploughing.

Just in proportion as the farmer has more organic matter mingled through such a soil, and timely cultivation given, so will it be cured of those **bad points** of character, and show **less temper** in its management.

We have also **kindly** and **grateful soils**, yielding good and abundant returns for labor and manure intelligently applied. As a rule, these are loamy soils, having sufficient sand and organic matter in them, well mixed, to enable them to be worked easily, and having

sufficient clay to preserve and hold in readiness the plant-food derived from the manure they receive. These are the most pleasant soils to manage.

Next comes the **invalid or sick soil**. It is with soils as with individuals; there are **many causes** for being in an unhealthy condition. Soils generally become sick either from the presence of some **objectionable** matter in the soil, or something is **absent** which the plant wants. Drainage and deep autumn cultivation will generally meet the difficulties of the first case; in the other class, we have seen in a former chapter that if the plant has not all the materials it requires, it shows it by a sickly appearance. The bill of fare of a plant is very long; and, like the weaver working on a fabric requiring many colors, if he runs short of one color, the whole work is stopped; if he wants a **red-colored yarn**, and has all the other colors in abundance, the work is at a **standstill**, and cannot proceed until the proper color is supplied; so with the plant, if one of the dishes named on its bill of fare is wanting, it makes no difference **how much** of the others it may have, it **cannot proceed in its growth**. Hence that law of **agricultural science** which tells us that it is those portions of the plant food which are **least abundant** in the soil, which **measure its fertility**, and not those portions which are most abundant. Like a chain, it is the **weak link** which measures its entire strength.

CHAPTER XXVIII.

ANALYSES OF FIVE DIFFERENT KINDS OF SOILS.

THE soil may be regarded as a mixture of many different substances, each having its own peculiar prop-

erties, and each giving its own influence to determine the general character of the soil. These substances were obtained from different sources, and are frequently mixed in very irregular proportions; for these reasons we must depend upon the chemist to separate the several substances which compose it, and determine their respective quantities and their condition. In this way we may learn what materials are in the soil, and thus find out its capabilities.

The following table represents the chemical analyses of five different kinds of soils. The word "trace" means that so small a quantity of the ingredient was found that it could not be weighed by the chemists who performed the analyses:

	Fertile Soil.	Barren Soil.	Rich Clay.	Good Loam.	Calca- reous.
Potash.....	1.03	Trace.	2.80	.80	.....
Soda.....	1.97	Trace.	1.44	1.50	.....
Ammonia .....	.06	.....	.....	.....	.....
Lime.....	4.09	Trace.	.83	1.28	52.33
Magnesia.....	.13	Trace.	1.02	1.12	} 2.86
Peroxide of Iron.....	.35	} 2.00	4.87	3.41	
Protoxide of Manganese.	9.04		.....	.....
Protoxide of Iron.....	.29	Trace.	2.80	.80	.....
Alumina.....	1.36	.50	14.04	3.58	.....
Phosphoric Acid.....	.47	Trace.	.24	.38	Trace.
Sulphuric Acid.....	.90	Trace.	.09	.09	Trace.
Carbonic Acid.....	6.08	.....	.....	.92	44.70
Chlorine.....	1.24	.01	.01	Trace.	.....
Soluble Silica.....	2.34	.....	.....	.....	.....
Insoluble Silica.....	57.65	96.00	61.20	} 81.26	} .26
Insoluble Silica (sand). .....	.....	.....	.....
Organic matter.....	12.00	1.50	8.55	2.43	.....
Water or loss.....	1.00	.....	4.91	3.27	.....

It will be noticed that the list of substances found in soils is **greater** than those found in the **primitive rocks**; but we must remember the fact, that, in

addition to the rocks, the atmosphere and the sea **contributed** in course of time to the soil, and in this, they were assisted by the operations of animal and vegetable life.

You will notice the great amount of **silica** in all the soils, except the **calcareous**, but especially in the **barren one**. Silica may be looked upon as forming the main bulk of all sandy, loamy, and clay soils, to which the potash, soda, etc., give fertility. Phosphoric acid, like silica, is a **weak acid** at low temperatures; but when heated it becomes exceedingly powerful. It rarely amounts to more than .5 per cent. of our richest soils, and many fertile soils contain a much smaller supply. Its value as a constituent of good soils has long been acknowledged, and all our cultivated plants **require a supply**. It looks as if it were a provision of nature to enable our crops to be of proper **feeding value** in the support of animal life; for the plant makes as powerful a claim on the soil for **phosphoric acid** as the animal does on the plant for this material, which is a necessity to it **for the formation of bone**.

CHAPTER XXIX.

DOUBLE SILICATES AND THEIR VALUE IN THE SOIL.

IN the above analyses **silica** and **alumina** are given separately; but in the soil a part of the silica is combined **chemically** with a part of the alumina, forming a silicate of alumina. This substance is the **essential ingredient** in pure clay—such as the fine white clay used by the potters in making china. Alumina **does not** enter the plant at all. You will discover that it is the only substance given in the analyses of the soils

which does not occur in the **ash of plants**. Although alumina thus remains outside the plant, yet it is found to serve a very useful purpose by acting as a kind of **waiter**, holding the plant food in readiness for the use of the plant. It does this by combining with silica, and at the same time with some other substance of plant food, forming what is called by chemists **double silicates**.

The chief double silicates are these:

- Silicate of alumina and soda.
- Silicate of alumina and lime.
- Silicate of alumina and potash.
- Silicate of alumina and ammonia.

It is found that the silicate of alumina combines more readily with **ammonia** than any of the other changeable components, the next favorite being **potash**, then **lime**, and lastly **soda**. Therefore, if a silicate of alumina and soda meets in the soil with lime, the soda is given up, and the lime takes its place. In the same way, lime is rejected for potash, and potash given up for the greatest favorite, ammonia.

Now, ammonia is the most useful to plants, potash next, lime next, and soda the least of all.

The great use of the double silicates in the soil, therefore, is their power of receiving and **holding in chemical union** ingredients from the air and the decaying **organic substances**, the most valuable kind of plant food, which they **give up** to the plant when required. The roots of plants have a **greater control** over the changeable components of the double silicates than the silicate of alumina has itself; so that they are able to take from it the materials they require, and the silicate of alumina then seeks some more of that valuable plant food, ammonia, potash, etc., which

the plant utilizes again when it needs it. **This action of the double silicates** we shall find to be of great importance when we come to consider the action of manures.

CHAPTER XXX.

TILLAGE AND ITS BENEFITS TO THE SOIL.

THE successful growth of crops depends upon the soil containing a sufficient supply of plant food **in a soluble condition**; we have shown you that a soil may be unproductive even if it has plenty of plant food, by that food being in a dormant condition, or some poisonous substance being present.

That the soil **be suitable to the crop**, is one of the chief conditions of success. The farmer has no power over the climate, but **he can choose such crops** as he finds most suitable for it. Thus, some kinds of wheat grow best in the North, others best in the Middle or Southern States; also, some kinds of corn are suited for a short season, and others for a longer season, and so on.

But, granting the plant food in any soil to be sufficient, injurious matters absent, and the climate suitable, we yet require **a proper tillage** of the soil to develop its capabilities, and to make the most of all these conditions, so as to produce **the greatest yield of crops at the least expense**, and yet leave the land in as good, or **better, condition** for the next crop.

Baron Liebig compares the work performed by the plow **to the mastication of food** by those special organs with which nature has endowed animals. The comparison is most felicitous, and conveys the true idea clearly. We all know that food, unless it be well masticated, or ground down by the teeth, or other means,

gives up very little nourishment to the body; so it is with the soil, unless it be well broken down, thoroughly pulverized, and well mixed, the plant **will not be fully sustained.**

The natural agencies are always ready to assist. Weather—including frost, snow, and rain—is of prime importance. Rain is absolutely necessary to supply the water which enters so largely into the growing plant, and into which the plant food is dissolved. Without rain a country becomes **a desert**, unless water is brought from a distance and spread over the land by overflow, as in the basin of the Nile, or by artificial irrigation.

In the winter the rain takes the form of snow, and is then useful as a covering for young plants. Frost, also, is a great friend to cultivation by its acting upon the moisture in the soil, bursting asunder the **tough clay**, and exposing immense surfaces to the action of the air.

Ammonia consists of nitrogen and hydrogen chemically united, and exists in the air. You will remember that plants **cannot absorb nitrogen from the air**, although four-fifths of the air consists of this gas; to be of use to the plant it must be united with other elements, as in **ammonia** and **nitric acid**. The flashes of lightning cause the nitrogen of the air to unite with the oxygen and form the nitric acid, which is washed down into the soil by the rain.

Another friend of the farmer is the common **earth-worm**. This worm lives by swallowing earth containing vegetable matter, from which its digestive organs extract nourishment; the soil it then brings up and casts out in a finely divided state. Darwin calculated that in many places more than ten tons of earth on every acre of ground pass annually through their

bodies, and are thus brought to the surface. The worm-burrows, too, which are often five to six feet deep, assist in draining the soil, and form passages into which the air and roots of plants can enter.

Spade cultivation may be set down as **the model**, to which we may strive to attain, as near as possible, by such means as are within our command. The advantage of this cultivation is the **greater extent** of feeding ground for the crop without **extending the boundary lines**, and likewise the easier search for food. We must do our best to reach these ends; but it is hardly possible, with our present appliances, to come up to the efficiency of the spade. Steam cultivation is a very valuable agency in this direction, and, when used in the fall of the year, it goes far towards giving the land that thorough working which the spade accomplishes. The steam plow turns a furrow twelve to fifteen inches deep, and twelve acres a day, in the tough clay soil of Scotland. The work of the steam plow in the large prairie fields of the Western or prairie States would be of incalculable benefit to the tillers of that soil. In addition to the work being better done by a deeper tillage, causing better drainage, increasing the feeding ground, and enabling crops to better withstand the drought, as well as a prolonged and steady growth by the deep anchorage, and a gradual perfecting of the crop instead of a hasty mushroom growth, the relief to men and horses, who are required to toil to exhaustion in the hottest season of the year, plowing and harrowing for the winter wheat, would far exceed the cost. It is no wonder that farmers become prematurely old, when their toil so frequently brings them to the verge of exhaustion, and for all their toil getting unsatisfactory returns. The inventors of the reaping and binding machine conferred a great boon to

the farmers of the broad prairies by making it possible for them to care for a large extent of wheat at the minimum of cost. In like manner, the inventor of a steam plow, which will be as practically useful, will be entitled to the warmest gratitude of farmers—especially the prairie farmers, whose soil is peculiarly adapted by its nature to be benefited exceedingly by it.

We hope, before the end of the present decade, that a steam plow will be a familiar sight in the Valley of the Mississippi.

CHAPTER XXXI.

THE WORK OF THE PLOW AND PLOW-PANS.

ONE of the foundation stones upon which a good tillage of the soil must rest is a **thoroughly complete fall cultivation**. A **satisfactory cleaning of the land**, and the **judicious deepening of the soil before winter**, will greatly favor an increased production, and assist in rendering the work more economical, and the soil more easily prepared for a good seed-bed.

Various kinds of plows are made to which horse-power is applied. In ancient times the plow was simply a pointed and forked piece of a tree, and this was dragged through the soil. After a time, the point entering the ground was shod with iron to give it a greater power of endurance; then the whole point was made of iron, and a "mould board" was added, of such a shape as to receive the layer of soil under which the point has entered, and to raise and turn it to one side.

The plow has been improved in strength and design, so that a very high standard of every quality is reached. The plow of the present day represents the thoughts of generations of intelligent plowmen.

With the plows adapted to horse-power we go about five inches deep, and throw the soil in ridges, so as to expose as much surface to the weather as possible. By continually plowing in this manner, and to this depth—the horses and men walking along the furrow, and the sole of the plow sliding and pressing down the subsoil—that soil is often squeezed and hardened into a dense layer, through which the roots of plants can pass with difficulty, and sometimes not at all, and through which the water cannot penetrate, and of course stagnates. There is too much of this pan now in the prairies. This hard layer is called a “**plow-pan.**” To break up this pan, and stir the subsoil, and make a way out for the water, another kind of plow is used to follow the ordinary one, called a **subsoil plow**, which breaks and stirs up the subsoil **without bringing it up to the top.**

Some Scotch farmers use one of their old plows for this purpose; the mould-board is taken off, and the “shear” well pointed; in this condition it is found to make a very satisfactory subsoil plow. Another plow for breaking up the “pan” is sometimes used; it is made like the ordinary plow, but stronger, and going much deeper, and brings up the subsoil to the surface; but in this case so much power is needed to break, lift up, and turn over this great depth of soil that steam power must be employed to draw it.

CHAPTER XXXII.

OTHER “PANS” AND SUBSOIL PLOWING.

PANS may be due to other causes besides constant surface plowing. In some districts, especially where the soil is formed from the breaking down of the red

sandstone which contains a large quantity of iron oxide. As this gets washed into the soil it forms a kind of cement, binding the materials together into a hard cake, which is called an **iron pan**. The **cementing power** of iron rust is very great, as may be satisfactorily proved in old roads in the neighborhood of abandoned **iron furnaces**, where iron ore has been hauled in carts; the particles of ore sifting through the openings of the carts, and mixing with other substances, it **incorporates the whole in one mass**.

There is a complete illustration of this cementing power of iron particles in an old wagon road in the neighborhood of the Mt. Savage furnaces, now for several years unused, where a cake is formed as solid looking as pig-iron, but light in weight in proportion to its size; thus showing how small a quantity of iron oxide is necessary to form a "**pan**."

In other soils where there is **much lime** naturally, or where lime has been put on the land **too freely**, it has sunk into the soil as far as it has been stirred, and there formed a hardened cake, called a **lime pan**.

In all these cases the use of the subsoil plow comes in place to break up the pan and open up the subsoil. But in **all soils**, whether a pan is formed or not, the **occasional use of the subsoil plow** for stirring up the underlying earth is beneficial, as it then admits air, and allows the deep roots to penetrate the subsoil to obtain nourishment, which is one of the objective points of good cultivation.

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CHAPTER XXXIII.

THE USES OF DIFFERENT KINDS OF AGRICULTURAL
IMPLEMENTS.

IN addition to the plow, the chief implements used in cultivation are the **cultivator**, the **hoe**, the **harrow**, and **roller**. These are used principally for clearing the land of weeds, and for preparing the surface for receiving the seed.

The cultivator consists of several tines slanting downward and forward. These, when drawn through the soil, help to turn over and break down the clods, and draw out the weeds to the surface.

Various kinds of hoes and harrows are used for turning over and breaking down clods, dragging out weeds, and covering seeds that have been sown. The hoe is chiefly used for clearing the land of weeds, or for ridging up the soil around the roots of some crops, such as corn and potatoes. Sometimes this is done by hand, as with a garden hoe, but when the crop is large, and sown in regular rows, the horse-hoe is used. This is drawn between the rows by a horse, and generally consists of several blades, fixed in a frame at the proper distances apart, so as to throw up the soil against the plants on each side, and at the same time cut off or root up the weeds in the spaces between the rows.

Harrows are made of various sizes and patterns. Heavy harrows, or drags, are used for turning over and breaking the clods on plowed land, or for stirring land which has been lying fallow. Lighter harrows are used for bringing weeds to the surface and collecting them;

and lighter ones still, made of chain work, are used for covering seeds which have just been sown, and for lightly stirring among grass and young wheat or oats.

The roller is principally used for pressing the soil around the seeds or young plants, so as to keep them moist, and enable the fine roots to take hold of the soil.

A rough kind of roller, with projecting points and notches, called a clod crusher, is sometimes used to break down the hard lumps of soil, so as to expose a greater surface to the atmosphere.

There is yet another clod-crusher, which is considered by many the most perfect form of all. It consists of a series of wheels, alongside each other, each having an independent action. It is very heavy, and was designed to grind and crush up intractable clods, and reduce heavy clay to a fine tilth. They are, however, of equal, if not greater, value as compressors of light soils, before wheat sowing, to roll winter crops in the spring, and consolidate the land where the crops are attacked by the wire-worm.

CHAPTER XXXIV.

PREPARATION OF THE SEED-BED AND SEED SOWING.

OUR next important subject is the preparation of the land to form a suitable **seed-bed**, in which the seeds will have the best chances of procuring moisture, warmth, and air, which are so necessary for their growth. The preparation of the seed-bed will vary with the nature of the soil, and with the **size and character of the seed**. But there are some points which must always be carefully attended to. In the first place, it is necessary to procure **plenty of room** for the roots of the plants to reach downward into the soil. By deep

plowing and the use of the subsoil plow, especially in clay soils, the soil is loosened to a good depth and the roots enabled to penetrate it in search of food.

The roots of winter wheat have been traced to a depth of seven feet in a loose soil forty-seven days after sowing.

For securing germination in its healthiest form, the **regular admission of moisture** into the seed is a matter of the utmost importance. Special provision has been made for carrying this moisture into and throughout the seed. We find a series of **irrigating channels in the seed** used for this purpose. Thus, water supplied to the surface of the seed does not simply moisten the surface; and so penetrate more and more deeply into the seed, but, under healthy conditions, the water is **carried through** the seed by those irrigating channels, and thus a more **equal distribution** takes place—consequently a more uniform swelling of the seed. If the seed becomes “dirty,” the entrance to those irrigating channels are largely **closed up**, and, as a consequence, an irregular distribution of moisture, resulting in an irregular germination and a weak and sickly plant.

The next point of consideration is the depth to which the seed should be sown; this depends upon the supply of air and moisture. If the seed lies too far below the surface of the soil it might be kept moist enough, but it will not obtain sufficient air to supply it with the oxygen it requires. Again, upon the other hand, if it is too near the surface, it may get alternately wet and dry with the rain and the sun. This prevents the steady growth of the plant, which injures its healthy development. The farmer has to judge by the **nature** of the soil, and the **climate**, and **size of seed**, how deep he will place it.

Then, again, it is necessary for the support of the young plants, or seedlings, that the soil should lie **close around them**, without excluding the air from the roots. In some soils it is necessary to sow the seed immediately after plowing, and then to roll it at once, to press the earth close to the seeds; in others it must be left two or three weeks for the moisture to rise to the surface, by capillary attraction, before the seeds are sown.

Wheat requires a **firm support** around its young roots, and yet the soil must not be hard and close, or the roots will not be able to grow into it freely in search of food. The best preparation for a seed-bed for wheat is **to grow a crop of clover** upon the land just before the wheat is sown. The reason for this will come up with the subject of rotation of crops.

CHAPTER XXXV.

ELEMENTS OF THE SOIL EXPLAINED.

HAVING treated of the cultivation and formation of the soil, the next subject which presents itself is the **exhaustion** of the soil; but, in order to fully comprehend this subject, we will take another chapter in chemistry. We wish to impress upon your minds the important fact that chemical knowledge, to be useful, must be **exact**. You must endeavor to get a clear conception of the facts we are about to take up, and not pass them over till they are all thoroughly understood.

It has been ascertained that the whole world, and all that is in it, as far as known, is built up of about **sixty-three elements**, some of which exist in great abundance, and others are very rare and in small quantities

Some of these elements exist in a free state, so that we can easily see them and handle them; while others are united with one or more other elements, and are then different in **appearance**, and even **qualities**, to the elements of which they are formed.

Of the sixty-three known elements **forty-eight** are metals, such as gold, silver, copper, tin, and iron; and some are very rare, and unknown except to the chemist.

The other **fifteen elements** are not metals, but act a more important part than the metals in the construction of the earth and the sustaining of its inhabitants. Neither one of the two classes, however, could do much without the other. The list of the **fourteen elements** given below are of importance to agriculture, with which we must become familiarly acquainted in order that we be exact in our knowledge.

The **non-metallic substances** are oxygen, hydrogen, carbon, and nitrogen, and are classed as organic elements; sulphur and phosphorus are classed as secondary organic elements; also silicon and chlorine.

The metals are: Potassium, sodium, calcium, magnesium, aluminium, and iron.

The first **four** on the list are called the organic elements, because the softer and more **important parts** of plants and animals are made up of particular compounds of **these elements**, and can be made from no other. It is also true that these same elements enter into and make up a large part of the inorganic world, as stones and earth; so you see you must be careful not to be misled by the term organic. It means that animals and plants are dependent in an especial manner upon these elementary substances for the **support of their organized soft parts**.

CHAPTER XXXVI.



ORGANIC ELEMENTS.

Carbon forms the chief bulk of all plants. If you burn a plant in a close vessel, admitting no oxygen, the black substance which remains is carbon, which is familiarly called charcoal. When **oxygen** is freely admitted to it, it combines with the carbon, and forms **carbonic-acid gas**.

Oxygen, in its free state, is an invisible gas; it forms one-fifth of the bulk of the atmosphere, and, in a combined state, forms seven-eighths of the weight of water, and nearly **half the substance** of the **whole solid globe**. It unites with nearly all the other elements to form **oxides**.

Nitrogen, when free, is also an invisible gas, forming four-fifths of the bulk of the atmosphere; but its most beneficial service to agriculture is in combination with hydrogen in forming ammonia, and with other elements in the form of **nitrates**.

Hydrogen, when free, is the **lightest** of all gases. Combined with oxygen it forms, by weight, one-eighth of water; and, when combined with nitrogen, it forms the valuable compound, ammonia.

Sulphur and **phosphorus** are called **secondary organic elements**, because they are not used to so great an extent in building up the structures of animals and plants as the four elements before named. They enter also into the composition of many inorganic substances, and form **sulphates** and **phosphates**.

Silicon combines with oxygen to form silicates—the most plentiful constituent in all soils, except peat soils. Fine white sand, flint, and quartz are nearly pure silica.

Chlorine is a greenish, choking gas, when free; but we generally find it combined with sodium, which then forms common salt, which is found in all plants.

CHAPTER XXXVII.

THE METALLIC ELEMENTS.

IRON is probably the only well known metal named among the elements in the foregoing list. It is always found in the bodies of animals and plants.

Potassium is the metal contained in potash.

Sodium is the metal contained in **soda** and **common salt**. It looks almost impossible that a bright **silvery metal** can exist in the crystals of common salt or soda, or in white powdery chalk, and yet it is the fact. It is an easy matter for you to satisfy yourself. You may procure at a chemist's a piece of magnesium wire (about ten cents a foot); you will find it a dull whitish metal, but it is quite bright when newly made; it quickly attracts oxygen from the air, and becomes tarnished. Take one end with a pair of pincers, and hold the other end in the flame of a lamp or gas burner, the metallic wire takes fire and burns with a **brilliant light**. The metal, **magnesium**, is now combined with the non-metallic gas, oxygen, and forms the compound magnesia, which falls down from the dazzling flame in the form of a white powder—the very same which is used for medicine, under the name of calcined magnesia, which must contain the metal disguised in this curious form.

Calcium is contained in lime.

Magnesium is contained in magnesia and epsom salts. And aluminium is contained in alum and clay.

It is wonderful to learn, also, that lime contains the silvery metal called calcium; and the dirty looking substance, **clay**, (when pure, however, it is white), contains the golden looking metal **aluminium**, used so much now in making watch-cases, chains, cheap jewelry, and mathematical instruments.

From what we have now seen, you will readily understand that some elements easily combine to form compounds. It is a strange fact that **elements most unlike combine most readily**, and that their compounds are very unlike any one of the elements from which they are formed.

CHAPTER XXXVIII.

THE BINARY COMPOUNDS AND THE FORMATION OF THE SALTS.

WHEN two elements combine it is called a **binary compound**. These are very important to agriculture. They are generally divided into two groups—acid oxides and bases. Water lies between the two groups, and acts as an **acid oxide** to the **bases**, and as a **base** to the **acid oxides**.

	COMMON NAME.	FORMED FROM.
Acid Oxides.	Carbonic Acid.....	Carbon and Oxygen.
	Sulphuric Acid.....	Sulphur and Oxygen.
	Phosphoric Acid.....	Phosphorus and Oxygen.
	Nitric Acid.....	Nitrogen and Oxygen.
	Silica.....	Silicon and Oxygen.
	Water.....	Hydrogen and Oxygen,
Bases.....	Ammonia.....	Nitrogen and Hydrogen.
	Potash.....	Potassium and Oxygen.
	Soda.....	Sodium and Oxygen.
	Lime.....	Calcium and Oxygen.
	Magnesia.....	Magnesium and Oxygen.
	Alumina.....	Aluminium and Oxygen.
	Iron Oxide.....	Iron and Oxygen.

An **acid** joined with a **base** forms a **salt**. For example, carbonic acid with the base, lime, forms the salt carbonate of lime; so, nitric acid combines with the potash to form nitrate of potash, commonly known as saltpetre, and so on.

We will now take into consideration the most important salts of interest to the agriculturist:

The chief of these are the **carbonate of potash**, forming the greater part of the ashes of burnt wood; the **chloride of potash**, which is the principal substance in the manure called kainit; and **nitrate of potash**.

Carbonate of soda occurs in the ash of many plants, and nitrate of soda is Chili saltpetre, often used for manure. The commonest soda salt is the chloride of sodium, or common salt. Unlike most salts, this is formed by the direct union of **chlorine and sodium**.

When the **carbonate of lime** is roasted in a kiln, the carbonic acid is driven away, and lime only is left, which is called quick-lime; it is then very porous, and has a metallic ring. When water is poured on it a chemical action takes place by its combining with the lime; it then produces great heat, and forms the hydrate of lime, or slaked lime; but if it is left exposed to the air, the carbonic acid, which was driven from it, seeks to reunite, and brings it back to its **original condition**. Masons are well aware of this fact, as when they slake the quick-lime they immediately cover it with sand to keep it from the air, or rather the carbonic acid in the air.

Another useful salt of lime is **gypsum**, which is a sulphate of lime. But the most important of all the salts is the **phosphate of lime**, because of its entering so largely into the economy of both animal and vegetable life.

The silicates form an important class of salts, as it is principally by their aid that the crops are supplied with silica, as well as with the base with which the silica is combined. Thus the silicate of potash supplies both silica and potash; silicate of lime, both silica and lime, and so on. You may refer to what is said about the double silicates in a former chapter.



CHAPTER XXXIX.

THE ATMOSPHERE.

THE atmosphere is so important to the growth of plants that it is necessary we should have a distinct knowledge of its **nature** and **composition**. The great bulk of the air consists of **oxygen** and **nitrogen**, in the proportion of one of the former to four of the latter, **only mixed, not chemically united**.

To give you a clear idea of what we mean by mixed, but not chemically united, let us take some lard and put a little water into it; we can so thoroughly mix them that it will be difficult to detect the water, but still the two substances are only mixed; we will now put some potash into the mixture, and they become immediately united chemically.

Of those two gases it is only the oxygen which is active, entering plants by their roots, and it is also combined with many other substances in the air and in the soil, where, you will remember, it is to be freely admitted, by means of deep plowing and drainage, to give it the opportunity of rendering poisonous matters nutritious by its action. It is found by careful investigation, as we have before stated, that **free nitrogen does not enter** the plant at all; and as nitrogen is

one of the necessary organic elements, the plant must obtain it in some other way.

The nitrogen in the air acts only as a **regulator** to the oxygen, preventing its too violent action.

Besides the oxygen and nitrogen, the air has always mixed with it **four substances**, which are good friends of the farmer. These are **watery vapor, nitric acid, carbonic acid, and ammonia**. Although these exist in the air in very small quantities in proportion to the general bulk, yet if we take into consideration the **vast extent** of the atmosphere, we shall discover that there is really a large supply of these substances. The carbonic acid in the air is the great supply of carbon to the crops.

The nitric acid and ammonia are washed down into the soil by the rain, and, as they are very soluble, they become at once suitable for the nourishment of the plant. The power of the soil **to absorb** ammonia (nitrogen and hydrogen) is not confined to periods of rain, is not even confined to the periodical recurrence of dews; so often as the air is charged with carbonate of ammonia, and comes in contact with a surface of soil, so often will this soil be enriched by ammonia to the extent to which the air contains it. For this reason the soil should be open, loose, and porous, so as to make it accessible to the æriform fertilizers. This explains why cultivating frequently between root and corn crops is so beneficial. It has been estimated that an acre of land receives in these ways every year about eighteen or nineteen pounds of nitrogen. The other ingredient found in the atmosphere is watery vapor. This is simply water in the form of an invisible steam or gas. It is of use to the crops when it descends in the form of rain or dew.

CHAPTER XL.

THE DISSOLUTION OF PLANTS AND ANIMALS.

WHEN a plant or animal dies, the softer parts soon decay and separate into simpler chemical forms. This dissolution is caused by the growth of tiny living things, the germs of which are always floating in the air, except in keen frosty weather, which, with the aid of oxygen, break up the organic substances (which, we before learned, consist of oxygen, hydrogen, nitrogen, and carbon,) into the simpler substances, **water, carbonic acid, and ammonia**, each of which is only a binary-element compound.

If the animal or plant decays in the air, these gases escape or fly away in the air, causing an offensive smell; but if the decay takes place in the ground, the soil has the power of **absorbing these gases**. Clay soil has the greatest power of absorption, especially that portion of it which has taken the form of double silicates.

On account of this peculiar property, dry pulverized clay is one of the very best disinfectants, and makes an excellent dressing for "angry" wounds, because of its power to absorb the corrupting matter, and render the sores calm and clean.

The mineral or inorganic substances likewise **fall to pieces** in the soil, where they remain as carbonates, phosphates, and sulphates, ready to supply inorganic food to succeeding generations.

Thus you will perceive **the unceasing round** of change going on in the air, in the soil, in plants, and in animals, which the intelligent cultivator will wisely consider and utilize whenever possible.

In soil where there is a good portion of humus, it abounds with life. Many living creatures can be seen with the naked eye, but many more are revealed by the aid of the microscope. Grubs of insects feed upon roots of vegetables left in the soil, and they change their food into ammonia, and carbonic acid, and water, which is taken up by the soil. Some grubs, however, attack growing crops, and are, consequently, hurtful to them; but most of the grubs do more good than harm.

Growing plants which produce **real flowers and seeds, cannot feed upon decaying matter directly**; it must be changed into carbonic acid, nitrates, and ammonia before they will accept it as food. There is, however, a set of plants called **fungi**, but which are sporadic, belonging to the mushroom or toad-stool family, which possess the power of feeding upon vegetable matter **directly**, like animals. They exist in the soil, and are friendly helpers in preparing food for the higher classes of plants. In the days of witches, "fairy rings," which abound in old pastures, were an object of superstitious awe, and were long a puzzle to scientists; but the mystery was at length solved; they were found to be caused by fungi, which, commencing to grow in one spot, converted the **humus into nitrates**, causing the grass to grow in that spot a dark green tuft. The fungi spread out from that centre, continuing their work in a circle, thus feeding a small ring of grass, which grows greener than the rest; and so the "fairy rings" extend, growing larger and larger.

For the best conditions of forwarding these chemical changes in the soil, so that the farmer may be benefited by them, four things are absolutely necessary: (1) The presence of oxygen. Here we see the reason for deep cultivation and drainage, (stagnant water will never do),

by which the air, with its oxygen, can enter. (2) Moisture in moderate quantity must be present, such as is obtained by capillary attraction, as in a flower-pot. (3) Warmth, for the purpose of oxidation, which is more active in summer than in winter. (4) The presence of some base in the soil to unite with the oxygen to form nitrates. The best substance for this purpose is the carbonate of lime; the base, lime, unites with the nitrogen to form nitrates of lime. The lime is next discarded, and potash preferred, which then forms nitrate of potash, which, you remember, is very useful for the growth of the crops.

CHAPTER XLI.

THE CAUSES AND REMEDIES OF EXHAUSTION OF THE SOIL.

IN this elementary work we first considered the structure of the plant, and the manner in which it takes its food; we next took up the formation of the soil, and saw from whence it came; also its physical and chemical composition, from which much of the plant food is derived; next the best methods of cultivating that soil, so as to get the food ready for the use of the crops in sufficient quantity to sustain them to their full maturity; and next the chemical properties of substances.

We are now prepared to consider **the exhaustion of the soil**, and the best remedies for that exhaustion. When a soil has been cropped until one of the substances of plant-food has been used up, so that it contains no more in a condition to be acceptable to the plant, we say the land is exhausted.

We have already seen that the whole of the plant food in the soil is **never in a condition** to be acceptable to vegetation. The soluble parts only are suitable for plant food, and that portion only forms a very small part of the soil. The rest of the soil may contain a large quantity of these substances, but they are held in reserve, to be called into active duty, by the action of the oxygen and carbonic acid of the air. The awakening takes time; therefore the necessity and advantage of turning over the soil as much as possible, and as long a time as possible, before the crops require the food, so as to give the air time and opportunity to act upon the dormant portion to make it soluble, and consequently available for the plants. Should it happen that this opportunity is not allowed, or perhaps neglected, it may occur that one crop will use up nearly all the active matter of one particular kind, so that the next crop can only get a partial supply—that crop will suffer because the land is exhausted. You must note, however, that an exhausted soil **may be quite a good one**, if it only has the opportunity to recover itself, and also given time to change its sleeping matter into an active condition by the friendly helpers in the air. Some soils, however, are so deficient in some of the elements of plant food, that even if all the food in them was brought into an active condition, it would last but a short time, and the land would then be thoroughly exhausted, and could again be rendered fertile only by a supply of the substances it had lost.

In some portions of the Southern States the soil has been so long cultivated with one or two kinds of crops—as much as possible of cotton or tobacco being taken, and little or nothing put in—that large tracts of land have been exhausted and abandoned.

So, also, in the Northern States, immense crops of corn, wheat, and oats were grown by the first settlers, year after year, until the land would no longer produce these crops in paying quantities. These settlers moved farther West, and cultivated new soil, which in time became exhausted, and was abandoned in its turn. But this is very wasteful, and cannot long continue.

Before we go on to state how fertility can be restored to the exhausted soil, we must inquire **what substances, and how much of each**, have been taken from the land **by the crops** which have been grown upon it.

CHAPTER XLII.



SUBSTANCES USED BY VEGETATION.

WE learned in a former chapter, that the organic substances were those forming the softer parts, and the inorganic substances were those contained in the ashes left behind when the plant was burned. You had better now refer to them and commit them to memory.

It has been found by careful experiment, that of the inorganic substances named there, that some are not absolutely needed for every kind of plant; yet they are always found in plants when grown in a natural way. It is, therefore, safe to say, that they are beneficial to their healthy and complete growth.

In the forest planted by nature there is no exhaustion; neither is there any exhaustion in an uncultivated prairie; for as the trees and plants decay, their branches and leaves go back to the soil, and return to it the same substances taken from it by their growth, in addition to the carbonic acid and ammonia which they had collected from the atmosphere. The long roots bring

up nourishment also from the subsoil, which they leave in the form of decaying matter, or humus, on the surface soil, and must, for this reason, become richer for their growth. Even if a large portion of the growth is eaten by wild animals, it is only laid up for a time in their bodies, to be given up again to the earth when they die.

But it is a very different case when we grow great quantities of corn, wheat, cotton, or tobacco, and **carry it away** for human use. In this case the inorganic matters are carried away entirely from the land from which it was derived. Even should it be a grass field, in which cattle or sheep have been turned to graze, though they give back some of the mineral matters in their droppings to the soil, yet their bodies, which have been built up by the grass they have eaten, are at last taken away to be consumed elsewhere.

You can easily understand now, that if crops are **constantly drawn from the soil**, to be used by men and animals elsewhere, the materials of plant growth will be carried away little by little, until one or more of them, which is especially wanted by the crop, gives out, and the soil is thus exhausted. It is the ingredient which is least abundant that determines the fertility of the soil, as before remarked; it is the weak link in a chain that determines its entire strength.

Exhaustion **may be delayed** for a long time by returning to the soil as great a quantity as possible of the plants grown upon it. To sell **milk, cheese, beef, straw, or hay** from the land will surely impoverish it, because of the mineral ingredients they contain, as may be determined by the amount of residue shown when they are burned; but if you sell **butter or fat**, and **keep** all the rest on the farm, your land will get better; because if you burn butter or fat, you

will find no residue; from which fact we ascertain that their constituents came **from the air**, and **not from the soil**.

CHAPTER XLIII.

SUBSTANCES EXTRACTED FROM THE SOIL BY DIFFERENT CROPS.

THE substances taken from the soil differ greatly in quantity. One kind of crop takes proportionately a great deal of **potash**, as turnips; another very much **lime**, as clover; a third, **much silica**, as wheat. Each crop has its own pattern, so to speak, which requires a special set of substances to complete its construction.

To enable you to have a clear conception of the ingredients, and the quantities of each kind required, we shall give you a table, prepared by several eminent chemists, which will be quite instructive upon this important topic:

INORGANIC MATTER TAKEN FROM AN ACRE OF LAND BY A CROP OF GRAIN, ROOTS, AND CLOVER.

	WHEAT. 25 Bushels Grain. Lbs.	STRAW. 3,000 Lbs. Lbs.	TURNIPS. 20 Tons Bulbs. Lbs.	6 Tons Tops. Lbs.	CLOVER HAY. 2 Tons. Lbs.
Potash.....	7.49	18.21	125.73	75.95	52.
Soda.....	.97	.90	22.98	16.23	7.
Magnesia.....	3.07	4.11	12.27	9.27	35.
Lime .....	.85	9.34	37.87	69.81	111.
Phosphoric Acid.	11.87	8.15	31.11	27.87	20.
Sulphuric Acid..	.08	5.82	42.26	36.56	13.
Silica.....	.84	101.82	11.64	2.58	10.
Peroxide of Iron.	.20	1.23	3.71	2.58	3.
Common Salt.....	.03	.33	28.69	38.15	8.
Carbonic Acid...	.....	.....	21.71	21.	.....
Total.....	25.	150.	340.	300.	259.

If a crop is larger or smaller, the number of pounds will vary in proportion to the quantity produced. This table, however, gives us a very good idea of the quantities of the **different materials** which are drawn from the soil. We see that turnips require much more inorganic matter than clover, and that clover requires more than wheat; we see, also, that all the different kinds of crops require nearly an equal share of **phosphoric acid**.

The other cereals, such as oats, rye, and corn, resemble wheat closely in requiring nearly similar quantities of inorganic substances.

All the leguminous or pod-bearing plants, such as beans, peas, and vetches, resemble clover, in requiring a large proportion of lime and magnesia.

The analysis of turnips may also be taken to represent the root crops, including **mangels** and **potatoes**, although these belong to a different order of plants.

CHAPTER XLIV.

REMEDIES FOR EXHAUSTION.

WE have now seen that each kind of crop draws upon the soil for its own particular kinds of food, and in different quantities. It will be evident, then, that if we grow the **same kind of crop** in succession for a number of years in the same soil, some of its soluble substances will ultimately become **scarce**, and the land becomes exhausted. But besides the mineral matters, plants also depend upon the soil for a good deal of their **nitrogen**. This very important element is carried down into the soil by the rain in the form of ammonia and nitric acid; but a store of nitrogen is in

all fertile soils, contained in the **dead roots of former plants**, and in the decaying vegetable matter, or humus, which gives the dark color to the soil. The nitrogenous portion of the humus, like the inorganic matters, are liable to be exhausted by the continual cropping of the same kind of plants on the soil.

We have now come to the very important subjects: The **remedies** for the exhaustion of the soil, and how to prevent it.

There are three ways by which these ends can be attained: (1) By giving **the land rest**. (2) By a **change of crops**. (3) By the use of **manures**.

Fallow is a very old Saxon word, whose prime meaning is pale yellow or reddish yellow, and is applied to lands plowed, not for the purpose of **raising a crop**, but preventing the growth of any plants whatever, thus keeping the color of the field **a pale or reddish yellow**, and **not green with crops**. The land is then said to rest. The atmosphere during this rest has time to act upon the soil, if we let it; the rain, and snow, and frosts of winter break down and crumble the hard particles of soil, which affords the oxygen and carbonic acid an opportunity to work upon the dormant matters, and bring them into an active or soluble state, and a new supply of potash and other food will be got ready for the crop when the time of rest is over.

It is very important that **the soil be kept open** during the period of rest; for this purpose it should be occasionally plowed, harrowed, and worked over by the cultivator to keep open the soil to the air and to prevent the growth of weeds, which are sure to spring up from seeds already in the soil, or carried there by the wind. These weeds would **feed** upon the prepared food, and would produce large quantities of seed, which

would give the farmer no end of trouble for years. For fallow, then, to do its very best, the land must be kept, as its name indicates, **reddish yellow, and not green with plants** of any kind.

An agricultural chemist found that after a crop of beans there was in the soil $19\frac{1}{2}$ pounds of nitrogen per acre; but after the same field had been fallow, the next year it contained $48\frac{1}{2}$ pounds per acre. Another field, which had been sown with wheat, without manure, contained, when the wheat had been removed, $2\frac{1}{2}$ pounds of nitrogen per acre; after a year's bare fallow, it contained $33\frac{1}{2}$ pounds to the acre. The great danger to a bare fallow, especially on light soils, is that these nitrates and other soluble food **would be washed away**, the sandy soil not having the double silicates to take up and hold in store the soluble plant food.

The great danger to prairie and timber lands is the **washing away of the surface soil** into the rivers and creeks. Although the double silicates abound in these soils, yet, by the nearly impervious condition of the subsoil, the water is compelled to flow away from the surface, and carries with it the silicates and the fertilizing substances they contain, thus rendering the land unproductive. Drainage, to aerate, and allow the water to percolate through the soil and pass the fertilizing matters over to the safe keeping of the silicates till needed by the plant, will give a high per cent. of profit to the farmer for his outlay. In order to reduce the dangers to light soils of a bare fallow to a minimum, fallow crops are grown, which take up this soluble food and make it into green fodder or roots, which are plowed in or eaten on the land.

CHAPTER XLV.

FALLOW CROPS.

THE practice of giving the land rest is very old. We find the giving of the land rest enforced by the law of Moses, which requires the land to rest every seventh year.

Crops which are grown in rows wide apart, to permit the use of the one-horse plow, cultivator, and horse-hoe between the rows, are called **fallow crops**, because a great portion of the surface can be stirred and cultivated, and cleared of weeds, and exposed to the atmosphere almost as well as if no crop was grown upon it, and, at the same time, the soil is being profitably utilized by the growth of a supply of food, making a paying return.

The United States has so many different kinds of soils and climates within its borders, that it is next to impossible to enumerate all the crops that may be useful as fallow crops. We shall attempt, however, to give a few which have come under our own observation. In the New England States, the Northern and Northwestern States, the principal fallow crops may be turnips, mangel-wurzel, or beets, potatoes, and corn. The farmer must be governed by the nature of the soil and climate which he may use. The roots of these crops bring up plant food from the subsoil, or their broad leaves gather in great stores of food from the air, and thus fresh humus is formed, containing nitrogenous matter, which is left in the ground for the next crop. In the Central States, including Southern Illinois, the

castor bean and corn make good fallow crops. The castor bean probably surpasses all others for this climate; it is a rank-growing, deep-rooted, and broad-leaved plant, and three-fourths of what is sold of this crop from the farm is oil, whose substances came from the air, and not from the soil. The land, by this crop, is enriched and left in prime condition for the profitable growth of wheat or any of the cereals.

For the Southern States cotton plants make a good fallow crop, and will not impoverish the land under a good system of cultivation. The cotton fiber, when burned, leaves proportionately a small residue, and the oil contained in the seed did not come from the land; therefore the soil will remain fertile if the cotton-seed cake is returned to it. The washing away of the surface soil from fallows, whether bare or cropped, may be set down as the prime cause of the farmer's difficulty in maintaining his land in a profitably fertile condition. **Drainage, assisted by deep cultivation, will reduce the difficulty to the minimum.**

CHAPTER XLVI.

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ROTATION OF CROPS.

WE shall now consider the second way to prevent exhaustion of the soil. Farmers generally feel that they cannot let the land rest more than is absolutely necessary; therefore, instead of having the land fallow, they make a set of changes of crops, called a **rotation**, or **round**.

You have learned that the different kinds of plants grown for a crop use the same substances, but they show a great variation in the quantity required by

each; therefore, if one kind of crop be grown on the same field for successive years, it is likely to use up one or more of the particular substances needed; the supply will, in consequence, become inadequate, and the crop then shows it by becoming yellowish, weak, and sickly. But if a different kind of crop be grown on the land, it may not require so much of that kind of food as the former crop did, but draws a different set of substances, and thus gives time for the others to accumulate in the soil in a soluble condition, until the first crop comes round again, when it will find a supply of its food ready for its use. But a good farmer does not wait till his land becomes **sick of a crop** before he changes it; he gives a regular round, or succession, of crops to prevent this.

The principle to be kept in view, in fixing on a rotation of crops, should be the **succession** which is best suited to draw from the soil the **largest net return**, while the capabilities of the land are at the same time **maintained and increased**.

There is a rotation common in England called the Norfolk course, from which we may get some instruction by investigating the reasons for its being a general favorite in many localities:

First year.....	Turnips.
Second year.....	Barley.
Third year.....	Clover.
Fourth year.....	Wheat.

Let us examine this course by the table given in a former chapter. Turnips take out of the soil large quantities of potash, soda, phosphoric acid, sulphuric acid, and chlorine. The second, barley is sown, which requires much less potash, soda, sulphuric acid, etc., but requires much more silica. The third year comes the clover, requiring a moderate amount of potash and sulphuric acid, very little silica and soda, but a large

supply of lime and magnesia. In the fourth year comes wheat, requiring a large amount of silica, but a small portion of the other substances. By this time the soil has been able to recover itself; the potash and other substances required in large quantities by turnips have been rendered soluble, and have accumulated, and the land is again in order to begin the course anew.

The rotation practiced by many intelligent farmers in the United States is: First year, clover; second year, wheat; third year, corn; and fourth year, oats; then comes clover again.

The practical considerations in favor of a rotation of crops are the **cleanliness of the land**; the **continuous supply of food**; the **distribution of labor throughout the several seasons of the year**; and the consolation, if one kind of crop fails, the farmer will not be in the "slough of despond." The adaptation of our farm products to the general wants of the people, as well as the varying climatic conditions, argue also in favor of a variety of crops. The alternation of green crops and root crops with cereal crops may be set down as an **axiom of good and improved agriculture**.

CHAPTER XLVII.

MANURES—THE GREAT REMEDY FOR EXHAUSTION.

WE have now come to the great remedy for the exhaustion of the soil, brought about by any cause; it is the use of manure.

The term manure, in its modern meaning, includes every substance, whether of vegetable, animal, or mineral origin, which, when applied to the soil, has the

effect of increasing its fertility. Its ancient meaning was: **Worked over by hand**. In this sense it was applied to the manual labor which made the land fertile. Shakespeare uses it with this meaning in "Othello" by the mouth of "Iago," when speaking of a garden. He says: "Either to have it sterile with idleness, or manured with industry."

There are **three principal modes** in which manures act upon the soil so as to enable it to grow more and better plants.

(1) They **supply deficiencies** in the soil, by giving to it substances which were wanting.

(2) They act **mechanically** on the soil, by rendering clay lands lighter and more open; or supplying sandy soils with humus, by giving it a closer body, thus enabling it to hold plant food, and encouraging capillary attraction.

(3) Some act as a **stimulant**. They do this by causing the soil to give up for immediate use the **reserve store** of plant food, instead of **adding more**. They drive the soil to do more work in a given time, as a horse is driven by the spur.

Some kinds of manures serve all three purposes; some two of the three, and others only one. The various manures used at the present day may be considered as belonging to the following classes:

1. Green manures.
2. Farm-yard manures.
3. Calcareous manures
4. Artificial manures.

The term **green manure** is applied to the system of growing a crop for the purpose of plowing it into the land. If a crop grown upon a field is returned to it, it looks like giving back to the land that which was only its own; but the advantage gained becomes palpable

when we consider how much deeper the roots of hardy plants go down for their food than those of the more delicate kinds cultivated for a crop. Thus the plant food is brought where it can be used, which was before beyond its reach.

Two very opposite classes of soil are benefited by this system. If a hardy crop, such as buckwheat, is sown upon **a thin soil**, and turned in just at the time it begins to **flower**, a large increase of organic matter is thus added to the soil. The advantages are very soon apparent; for the soil is enabled to hold larger supplies of moisture, and can take in more gaseous matter from the atmosphere.

The growth of clover is one of the most general means of improving the soil. It matters not whether it be on **light lands**, or **heavy**, or lands of the **intermediate** classes; in each case we see the fertilizing powers of all these soils being improved and increased. The clover crop is, in some respects, an exceptional one, because it is allowed to stand for a longer period before being plowed in. In the meantime, it is not only making growth **above ground**, but also **deep into the subsoil**. We must not forget the fact that the growth **beneath** the surface is proportioned to the growth **above** the surface; therefore, if the growth above the surface is eaten down, the extension of the root suffers in proportion.

CHAPTER XLVIII.

CONCERNING FARM-YARD MANURE.

FARM-YARD **manure** has long been acknowledged as the best manure used on the land. The manure produced by different animals is not of the same quality; its value is also affected by the food the animal receives.

From full-grown animals the manure is rich in nitrogen and phosphates. From young animals and cows giving milk it is much poorer, because much of the food goes to build up the bones and flesh. The milk also contains nitrogenous matter and mineral substances; the manure, therefore, is poor in these substances. The quality of manure, as we just now said, is greatly affected by the kinds of food the animals receive; thus, animals which receive **a ration of oil-cake** will produce very much better manure than those fed upon straw, grass, or hay, because the oil-cake contains a large amount of **nitrogen, phosphoric acid, and potash**. Farmers, on this account, often find it profitable to buy oil-cake to feed to their animals, the manure being then richer and more valuable to the land.

A ton of farm-yard manure contains about one thousand, five hundred pounds of water, about four hundred and fifty pounds of solid matter, and about fifty pounds of soluble fertilizing substances, mainly ammonia, silica, phosphate of lime, lime, magnesia, potash, soda, common salt, sulphuric acid, and carbonic acid. We have here, then, all the substances required by plants.

You will notice the large quantity of water and insoluble matter in farm-yard manure, and will be inclined to think that it is both unprofitable and laborious to haul two thousand pounds to supply only fifty pounds of fertilizing matter. Yet, for all that, the intelligent farmer finds it to be one of the **most economical** and useful manures that can be used. Its bulk is useful to most soils; for it acts physically by binding light loose soils, and upon heavy soils by separating them and making channels for air and water to penetrate. Upon either light or heavy soils it is also very valuable, because of the carbonic acid generated by the decay of the vegetable substances it contains, which acts upon the dormant matter already in the soil, and changes it into soluble plant food.

Its great value consists in the fact that it **returns to the soil the very substances which were taken from it** by the plants; therefore it pays back to the soil part of the loan made by it.

Any farmer who neglects his farm-yard manure, thinking to make up the loss by artificial manures, will find himself most egregiously in error, and will be ready to join in the exclamation: "He that trusts to artificial manures, expecting them to supply **all the requirements** of the soil, will find such trust a delusion and a snare!"

CHAPTER XLIX.

HOW TO INCREASE THE FERTILIZING POWERS OF MANURE.

THE superior **quality** and **value** of the manure of animals fed upon rich foods, such as oil cakes, as a means of producing meat, has been fully tested. The

investigation of this subject by Lawes and Gilbert, of England, places facts before us of immense value. It is shown by the scientific inquiry of these gentlemen that it is possible to obtain from a ton of each of the following named foods a manure enriched with fertilizing substances valued as follows:

BASE OF VALUES.

If one ton (2,240 lbs.) of pure guano be worth.....	\$60 00
Then manure from 1 ton decorticated cotton-seed cake is worth.....	32 50
Then manure from 1 ton rape cake is worth.....	24 50
“ “ “ 1 “ linseed cake is worth.....	23 12
“ “ “ 1 “ undecorticated cotton-seed cake is worth.....	18 75
Then manure from 1 ton bran is worth.....	12 50
“ “ “ 1 “ clover hay is worth.....	11 50
“ “ “ 1 “ oats is worth.....	8 75
“ “ “ 1 “ wheat is worth.....	8 25
“ “ “ 1 “ corn meal is worth.....	8 00
“ “ “ 1 “ meadow hay is worth.....	7 00
“ “ “ 1 “ oat straw is worth.....	3 50
“ “ “ 1 “ wheat straw is worth.....	3 00
“ “ “ 1 “ potatoes is worth.....	1 75

These results represent a great amount of labor and skill, and give information of real value to farmers in any country.

When farm-yard manure is placed in a heap it ferments. This fermentation is caused by the growth of immense numbers of tiny plants of the nature of fungi, the same as those found in fermenting wine or cider. These spores, or seeds of these plants, are always floating about in the air, and attaching themselves to any dead animal or vegetable matter, where they find the food they require, and begin to grow and multiply with great rapidity. As they feed upon the organic matter of the farm-yard manure, they break it up into **water, car-**

bonic acid, ammonia, and other organic acids, by the aid of the oxygen of the air. A great deal of heat is then produced; and if the manure is **kept moist**, and not allowed to get **too hot**, the organic acids combine with the ammonia and **hold it**; but if it gets **dry** and **too hot**, the carbonic acid is formed too rapidly, and combines with the ammonia, forming carbonate of ammonia, which is very **volatile**, and flies off in the air. On the other hand, if it gets too wet, the water filters through, and the organic acids and ammonia **flow away** into the streams. An intelligent farmer will study to avoid these losses. A strong **pungent smell** gives him notice of the waste of ammonia in the air, and **black streams** from the heap give him warning of the waste of organic acids and ammonia running away to a lower level. To cure the first, he should moisten the heap with its own drainage; to prevent the second, he should try to keep it drier by sheltering it from the rains, or he may collect the black drainage into a tank and use it on the land.

A thrifty farmer will be as careful about **the shelter** of manure as of any animal or implement on the farm; he will also see to it that the heap rests on a floor that is **impervious to water**. Without this, the shed will be worse than useless, because the urine will be lost by soaking away; the manure, in consequence, heats, and its virtues fly away. Ammonia is a coy fairy, and is easily caused to vanish in the air.

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CHAPTER L.

EXPERIMENTS WITH FARM-YARD MANURE.

WE wish to impress upon your minds the great superiority of manure stored up in **covered sheds**, with **tight floors**, over manure kept under the ordinary conditions. The following experiments will tend to convince the most skeptic upon this subject.

Lord Kinnaird, a Scotch land owner and farmer, in order to test the merits of manures kept in these **two ways**, measured off four acres of good soil; two of them were manured with the ordinary kind, and the other two with an equal quantity from a covered shed. The whole was planted in potatoes, with the following results:

RESULTS FROM THE ORDINARY FARM-YARD MANURE.	RESULTS FROM THE COVERED MANURE.
First acre..... 272 bushels.	First acre..... 442 bushels.
Second acre..... 292 “	Second acre..... 471 “
Total..... 564 “	Total..... 913 “

The difference **in favor** of the two acres supplied with the covered manure is three hundred and forty-nine bushels; but the advantage does not end here. The same land was next sown in wheat, and produced as follows:

WHERE THE ORDINARY MANURE WAS USED.	WHERE THE COVERED MANURE WAS USED.
First acre..... 41 bushels.	First acre... 55 bush. (^{61 lbs. per} bush.)
Second acre..... 42 “	Second acre 58 “
Total..... 83 “	Total..... 113 “

The difference again in favor of the land which was fertilized with the covered manure was thirty bushels. The yield of straw was also one-third more upon the land to which the covered manure was applied than on that where the ordinary farm-yard manure was used.

Upon **light lands**, which have little power of retaining the soluble matter contained in the manure, a great difficulty has been long felt; but very good results have been attained by applying well-rotted manure to the land **while it was carrying a crop** capable of rapid growth, it being able to use the soluble portions of the manure quickly.

The clover crop has been preferred for this purpose, to which the manure is applied at **various periods** of its growth. The results secured were the changing of the farm-yard manure into a living crop, and afterward making that crop yield plant food to the soil by plowing it in, which, by its **slow and steady decay**, gives nutriment to the wheat plant **progressively**. The wheat is then as fully benefited as if the soil had acted as the guardian of the store of plant food.

On light soils, then, manure should be applied in a well broken down condition at the time the plant needs it—that is, **in the spring**—or applied to a vigorous kind of plant while it is **in active growth**.

CHAPTER LI.

COMPOST HEAPS AND THOUVENAL'S PROCESS OF PRODUCING NITRATE OF POTASH.

COMPOST heaps are the means of making a very valuable manure for applying to the surface of the soil. They are composed of **vegetables** of various kinds mixed with **earth** and **quicklime**, with or without

salt; and, if properly and carefully made, will produce a good supply of the **nitrate of potash**. This substance is not purchased for use as an artificial manure, because its employment for the manufacture of gunpowder gives it a very high value. Wood ashes contain a considerable quantity of potash.

The means of producing artificially a cheap supply of the nitrate of potash was discovered in France by Monsieur Thonvenal in 1776. At that time there was a great desire in that country to get a supply of this substance independent of any foreign country, and the result was that enormous quantities were produced by Thonvenal's method. It may not be uninteresting to state here that Thomas Harris, in England, was granted a patent in 1741 for the production of saltpetre, or nitre, upon a plan similar to that of the Frenchman, for which he received a prize. And as early as 1630, David Ramsay, of Scotland, procured a patent "to multiply and make saltpetre in an open field in fewer acres of ground, sufficient to serve all our dominions." The art of war stimulated the inventors—not the arts of peace.

The **principle** upon which these nitre beds were formed is a matter of interest to the cultivator of the soil, because, by his practice, he has been producing nitrate of potash without knowing it, or the cause of a success which results so satisfactorily to him. The nitre beds are simply compost heaps, formed as follows: Good earth is enriched by the addition of **sheep manure, liquid manure, and quicklime**; the heap should be occasionally turned over; the nitrate of potash is formed within the heap, and is easily separated afterwards by washing the earth, and then evaporating the water.

The changes which take place are these: The **nitrogenous matters** in the manure decompose so as to form **nitric acid**; whilst the lime releases the potash from its combination in the soil; and, by the union of the nitric acid and potash so produced, we have the valuable fertilizer, nitrate of potash.

The system of plowing farm-yard manure into the soil, and then scattering lime on the surface, and harrowing it in, thus mixing the earth and quicklime, which finally mixes with the manure, brings about the condition favorable for the formation of the nitrate of potash. If the lime and manure should mix **on the surface**, much ammonia would be formed and **escape** in the air. Success in a certain mode of culture has directed many a farmer into a system which gives good returns, even when the why and wherefore is yet unknown to him.

CHAPTER LII.

THE USES OF CALCAREOUS MANURES.

LIME, chalk, marl, and gypsum are all classed as calcareous manures. They act in three different ways:

- (1) They supply plant food themselves.
- (2) They set free other substances in the soil, thus fitting them for plant food.
- (3) They act mechanically upon the soil.

Marly or calcareous soils would not be benefited by the addition of more lime; but clay soils, with a good supply of humus, are much improved by an occasional dressing—say once in five years.

Lime and chalk, as we find them, are united with carbonic acid gas. There seems to be a strong affinity between them; they are, therefore, very difficult to

separate, and it can only be done by submitting them to a strong heat. When they have been separated by **driving away the carbonic acid gas into the air** with the heat, they lose no opportunity of **uniting again**. This fact enables us to understand more clearly much that is peculiar to lime. The farmer is a great loser if he is careless in protecting his quicklime from the air, just the same as a builder would be who neglected to cover his slacked lime to be used for mortar; his loss would be discoverable to the eye, because it would have lost its power to make a good bond—that is, to crystallize—and would crumble out of the joints; but the farmer's lime, going into the land, he cannot so easily discover the loss, and he supposes something else is in fault. Intelligent farmers know the value of quicklime, and carefully avoid such waste.

All plants require lime in their food. Turnips and clover need a very large supply. A crop of two tons of clover uses one hundred and eleven pounds of lime, as will be seen by referring to the table given in a former chapter. The best form of lime intended for plant food is the **carbonate**. In the case of meadow land it is found after a top dressing of carbonate of lime, that the **sweeter and better kinds** of grass will spring up where it would not grow before. By the decay of the vegetable matter, too, the inorganic substances, which formed part of the dead plant, will be set free in the condition just right to the new crop.

You must bear in mind, however, that lime applied to the land, without manure, will be chiefly a stimulant; hence the truth of the old adage:

“Lime and lime without manure,
Will make both farm and farmer poor.”

CHAPTER LIII.

SUMMARY OF THE VIRTUES OF LIME.

V THE great value of the double silicates in the soil we noticed in a former chapter. We shall now endeavor to discover what is the **first step** in their formation, and how the farmer **can forward the work**. The application of lime in a caustic condition seems to have the power necessary to begin this chemical change; it displaces some of the alumina, or soda, if it happens to be present in combination with silica and alumina, and forms the first of the double silicates, viz.: Silicate of alumina and lime. The first step being attained by the energy of the caustic lime, the formation of the others follow in due order.

The following is the analysis of limestone found on land near Cumberland, Md., belonging to the Hon. William J. Read:

Carbonate of lime.....	80.93	per cent.
Combined silica and alumina.....	14.43	“
Alumina and oxide of iron.....	3.60	“
Moisture.....	1.04	“

The constituents of this lime, it will be observed, make it very desirable as a fertilizer for either clay or sandy soils. On clay soils it encourages the formation of the double silicates, and renders the soil more open and friable, which favors the admission of air; and, on sandy soils, the alumina gives them increased plasticity, and the lime and iron promotes the **cohesion** of particles, which, in turn, increase the power of the

sandy soil to hold moisture by capillary attraction, as well as forming the double silicates. The soil is thus enabled to hold plant food and moisture to an extent it never could do before. By this treatment the hungry and the stubborn soils are, to a great extent, cured of their bad propensities.

The action of lime in the soil may be summarized as follows:

(A) In its caustic state, as a hydrate of lime, it works out five distinct results:

(1) It acts rapidly on the organic matter in the soil by promoting decomposition, which changes nitrogenous matters into available ammonia.

(2) It neutralizes deleterious organic acids in "sour" land, and improves and sweetens the quality of the herbage.

(3) It favors the formation of nitrate of potash in the soil.

(4) It decomposes the silicates of the inorganic matter in the soil, setting free the alkalies (potash and soda), and thus changes dormant matters into those of an active character.

(5) It promotes the formation of the double silicates.

(B) When applied to the soil, in its milder form, as carbonate of lime:

(1) It contributes a supply of plant food.

(2) It neutralizes organic acids.

(3) It exerts a beneficial influence on sandy soils, by imparting a certain amount of tenacity; on heavy soils, by opening up and dividing it; and on peat soils, by breaking down their vegetable fibrous tissues.

Marl is a mixture of carbonate of lime and clay and siliceous matters—all of which act beneficially on the soil. Marls are so variable in their composition—the lime constituent being in some only eight per cent., and

others from eighty to ninety per cent.—that it is very difficult for the farmer to know their value, as he can have no certainty as to their composition.

Green marl generally contains about six per cent. of lime, and thirty-two per cent. of silica. Gray marl contains about forty-two per cent. of lime and twenty per cent. of silica. Chalk marl contains about fifty per cent. of lime and about eight per cent. of silica. It is, therefore, no surprise that the experience of those using them has been very varying in results.

The custom of using marls for fertilizing the soil is of great antiquity. Its utility was proven many centuries before the reason was known.

Gypsum is a sulphate of lime, often mixed with the carbonate in many marls and chalks. It supplies both sulphur and lime to the crops; but it has not the value of the carbonate in causing chemical changes in the soil.

CHAPTER LIV.

THE ARTIFICIAL MANURES—GUANO AND BONES.

ARTIFICIAL manures are substances employed to supply special wants of the plant, which may be absent or not abundant enough in the soil; and they are called **artificial** because the **art of man** is employed to import or manufacture them. Their introduction is of a **comparatively recent date**; but their use as special fertilizers has become very general.

It seems scarcely credible that within a period of less than **fifty years** these manures should have been brought to the notice of **farmers**, and to have secured such a universal acknowledgment of merit from them in every country where farming is a business, and not

merely a perfunctory occupation. It is proof positive that these manures **have met an important want**, hitherto unknown.

Baron Liebig, guided by a careful study of the elements of the food of plants, in 1840 pointed out the properties of guano as being the most infallible of all manures for supplying the cereals with food peculiarly adapted to their enrichment, and urged farmers to use it. The first introduction of guano into England was a consignment of thirty bags to a merchant in Liverpool, in 1839; and when the Royal Agricultural Society of England held a meeting in 1841, a sample of guano was placed on exhibition **as a novel curiosity**. Peruvian guano has always been accepted as the best; the first cargoes were exceptionally rich, and contained, on an average, seventeen per cent. of ammonia and from twenty to thirty per cent of phosphates.

This manure is the excrement of sea fowls, and their bodies added, which have accumulated for centuries and remained **uninjured by rains**. It was found on the rocky cliffs of islands off the coast of Peru in great quantities; indeed, some of the deposits accumulated to such an extent as to become two hundred feet deep. The richest deposits were first used; that in the market now is of less strength, and consequently of less value. The influence of the first Peruvian guano upon **strong clay** was unequalled by any competing manure; upon **light soils** it did not do so well, yet it was found to be very valuable.

Guano is adulterated by mixing it with yellow clay, gypsum, ground bones, chalk, common salt, sand, and powdered coprolites. A bushel of guano should not weigh more than fifty-six or sixty pounds, and should contain not more than two per cent. of sand and fifteen per cent. of moisture.

The first step towards the use of artificial manure was the **use of bones**—a practice which dates from the **commencement** of the present century. The constituents of bones differ according to the age of the animal—those of the young containing less earthy matter than those which are older. In full grown animals the earthy matter is about sixty-seven per cent. in thoroughly dry bone, the other thirty-three per cent. being the organic matter. The earthy constituents are **lime, phosphorus, magnesia, and soda**; the organic part is composed of **sulphur, carbonic acid, and ammonia**. The analysis of the earthy matter in bone is: Phosphate of lime, fifty-eight; lime, four; phosphate of magnesia, two; soda and common salt, three pounds in every hundred pounds.

CHAPTER LV.

PHOSPHATIC MANURE.

PHOSPHATES are combinations of **phosphoric acid** with a **base**. Phosphate of lime is by far the most valuable; it forms nearly half of the substance of bone. Phosphorus itself is found in combination with **blood, flesh, milk, and brains**. It has been estimated that each cow on a farm makes a demand for about eighty pounds of phosphates yearly, and **thirty gallons of milk** contain about one pound of the phosphate of lime. It is no wonder, then, that the use of phosphates has become an **established and remunerative practice**.

Superphosphate, or monocalcic phosphate, is too soluble, and apt to produce vegetation of an unhealthy character. The mixture of lime with it will remedy

this injurious action by bringing it back to a bicalcic, or more slowly soluble state.

Phosphates may be used with advantage on light loams, well-drained lands, pastures for dairy purposes, pastures where young stock graze, and the forcing of the germination of seeds, when it is desirable to push them past the period when insects are destructive.

The demand for phosphatic manures has been so great that the supply of bones is inadequate; therefore supplies from other sources had to be sought, and chemists set about the work of discovery. Sir J. B. Lawes, of England, was the successful investigator, and made the valuable discovery that phosphate of lime could be obtained from **certain kinds of rocks**, as well as from bones. Many doubted his ability to do so for some time; but facts are stubborn things, and, by actual demonstration, he established the truth of it beyond all cavil. It can hardly be estimated how enormous the advantage of this discovery is to the farmer.

The new product is known as mineral superphosphate of lime. The supply of phosphatic rocks may be had in various parts of the world, and thus causes an active competition, which keeps the price reasonable.

The mineral phosphate of lime, in its crystalline form, closely resembles the beryl or emerald; so slight is the difference, that mineralogists have been frequently deceived by it; for which reason it received the name apatite—a name derived from the Greek word *apateō*: to deceive.

Another supply of phosphatic manure has been recently discovered by Professor Wrightson and Dr. Munro, of Downston College of Agriculture, in England. The basic-cinder, obtained in the dephosphorization of iron in the process of making steel, is found to

contain from fifteen to twenty per cent. of phosphoric acid united with lime, iron, and alumina. This cinder, when finely pulverized, and liberally applied to the land, is found to be as good for the crops as the other well-tried phosphates.

If a soil contains little carbonate of lime, ground bones may be used, because the carbonic acid in the air and soil will soon change it into the slowly soluble bicalcic state, and form at the same time a carbonate of lime.

Superphosphate is an excellent manure for turnips, or other rapidly-growing crops, and acts not only as a **stimulant**, but also as a **food**. For wheat crops, and all grasses which are a long time in the ground, bone dust or bone ash is best, particularly if the ground seems deficient in phosphoric acid.

The adulteration of bone manure, when the bones are in fragments of a good size, is difficult. Bone meal is commonly mixed with oyster shells, the enamel of which **can be easily detected** with a magnifying glass; sand, chalk, and salt, are also added to increase the bulk and profit, not to the farmer, but the manufacturer. As a rule, bone manure is now professedly mixed with powdered coprolites and other phosphatic substances, thus forming valuable combinations, which are often profitably applied to the land in conjunction with guano.

CHAPTER LVI.

NITROGENOUS AND OTHER MANURES.

WE shall next consider the nitrogenous manures. The two substances, ammonia and nitric acid, with other nitric compounds, when applied to plants, are

taken up in a very dilute form by the roots, and help to form the nitrogenous part of their substance, viz.: **Albumen, gluten, and casein.**

Nitrates can only be applied profitably in the **spring**, when there is a **growing crop** to use them. If applied in the fall or winter, they would be **washed out** of the soil. Salt is sometimes applied to the soil for its soda, but its most important influence is in **checking plant growth**; it shortens and strengthens the straw of wheat, and, when used on crops which are too luxuriant, it is found to act beneficially by giving the plant time to elaborate and bring up the necessary mineral supplies, and thus increase the production of grain.

Soot is another manure used as a "top dressing," and is valuable for the ammoniacal salts it contains.

Tanners' bark is not generally valued as a manure; its best use is in the compost heap in conjunction with lime and earth, or with farm-yard manure, being principally composed of carbonate of lime and silica—substances existing almost everywhere. It is generally on this account neglected as a manure.

Saw-dust is useful only as a vehicle for taking up liquids; but in itself it is of little value as a manure. Mixed with **dilute sulphuric acid** it is one of the best materials for **fixing ammonia** in stables.

Gas-waste consists of ammoniacal liquor, which furnishes sulphate and muriate of ammonia. Gas-lime, or gypsum, is useful; but it should never be applied to the land in a fresh state on account of its sulphur. Gas-tar, which might furnish carbonic acid, is now put to a much more valuable use in the making of various perfumes and dyes.

Before closing the subject of special manures, we think it proper to call your attention to the following

facts, as they are worthy of the **farmers' best considerations**:

Do not forget that manures are only a **supplemental plant food**; the natural source of plant food is the **soil itself**. To pay large sums of money for expensive manures, and neglect the soil, is bad policy for the farmer.

Do not forget the good effects of **deep, thorough, and timely cultivation**; let the air and soil intermingle.

Do not forget the good effects of a **suitable rotation of crops**.

And, finally, do not forget that a farmer can sell and **permanently alienate only** that portion of the produce of his farm which has been supplied by the atmosphere. The production of butter does not exhaust the soil, because it is constituted of substances which came from the air. On the same principle, the putting of fat on full-grown animals, and afterward selling them, does no injury to the soil; but the production of milk and cheese is very exhaustive—also, the rearing of young stock. The soil requires a restitution of the mineral substances which have been taken away, such as the **phosphates**, and likewise the feeding of **oil-cake**.

A field from which no mineral substance is abstracted without being given back, **must increase in productive powers**. This may be set down as one of the most valuable of farmers' axioms, as it expresses the **whole groundwork of rational farming**.



CHAPTER LVII.

BOTANY—AGRICULTURAL PLANTS—THEIR GERMINATION.

IN the beginning of this book we had a few chapters describing a plant as the chief concern of all cultivation; we saw how plants feed upon the carbonic acid, and the nitrogen of the air; and also how they feed upon the organic and inorganic matters existing in the soil, or carried into it by the rains. We learned that these substances must reach the roots of the plants and their leaves either in the form of gas or perfectly and clearly dissolved in water, in which state it is drunk up by the tiny fibers, or the minute hairs, which abound in the young roots; we likewise learned that the entire plant was made up of wee, tiny cells, which were compared to very minute paper bags or boxes, shut up on all sides, and filled with a fluid we generally call sap. This fluid contains the food of the plant, which was in perfect solution, when taken in by the roots, and passes from bag to bag until it reaches the leaves, where the water is exhaled into the air; and those substances which were held in solution become plant nourishment under the influence of the light of the sun exerted upon the green matter in the cells of the leaves.

We may now go a little deeper into the mysteries of the growth of plants, particularly those which are cultivated for a crop.

We shall begin with the seed, and closely watch the process of its development up to the maturity of the plant. It must be clear to your mind that if we would

have a **perfect plant** we must have a **perfect seed**, otherwise the young plant will be defective, or the seed may not sprout at all. They should also be **fresh**—that is, they should not be exposed to the extremes of heat and cold, or heated in the shock or bin, and should be taken from the crop **preceding the planting** or sowing. Seeds which have a delicate outer skin, such as wheat, lose their moisture very easily, and become lifeless in a few years, and are, consequently, unfit for being sown or planted.

Turnip seed is **an exception** to the general rule. Farmers, in places where the turnip crop is important, have found by **experience** that it makes a better crop of bulbs and less leaf by being **two years** old when sown. When **new turnip seed** has been used, it has been found that the tops are larger and upper growth **so vigorous** that many of the plants make the effort to “**run to seed**” the first year.

Each seed has a germ, or embryo, which fills the whole seed in some kinds, as the pea and turnip; in others, as wheat, corn, oats, and the like, the germ occupies only a small portion of the seed, the rest of the seed being filled with materials provided for the support of the germ until the plant is developed enough to gather and manufacture its own food from the air and the soil.

CHAPTER LVIII.

GERMINATION OF SEEDS.

ALL plants depend upon the seed for their nourishment in the earliest stages of their growth. All seeds contain starch, gluten, and oil. In the first process of **germination** the gluten is changed by the oxygen

derived from the atmosphere into a soluble substance, which the chemists call diastase. This substance next acts on the starch or oil, and changes it into grape sugar, and, finally, into cellulose. Cellulose forms organized cells, which, in their progress of development, produce the first little shoot.

You will find it interesting and instructive to make an experiment in the germination of seeds, as follows: Take twelve peas, a like number of grains of wheat and corn; place them between the folds of a piece of flannel, and give them a supply of air, warmth, and moisture; or, if it be summer time, place them in a warm and moist corner of the garden, and mark the place of each seed; then, every twenty-four hours, take up one of each kind and notice the changes taking place. The moisture, as we stated in a former chapter, will find its way **into and throughout the seed** by a **series of irrigating channels** provided by nature for this purpose. Thus water penetrates more deeply into the seed, giving a more equal distribution, consequently a more equal swelling of the seed.

If the seed becomes "dirty," or partially coated with any sticky substance, the entrances by these irrigating channels will be **obstructed**; consequently there is an irregular distribution of moisture and faulty germination. Here, then, we have the why and the wherefore for a long established practice of every good farmer. Without the guidance of science, farmers look upon a **dry seed bed** as an essential condition for success, particularly where the soil is a clay or clay loam; the seed does not then become "dirty," and a **perfect germination** takes place.

We again return to our seeds. The moisture finds its way into the seeds, causing them to swell and enlarge; the oxygen of the air, entering at the same time, causes

those chemical changes to take place, before mentioned, leading to the growth of the germ into a complete plant. By the swelling of the seed the outer skin is riven and the young root appears, pointing downward; then the plumule shows itself, pointing upward, and soon appears above ground. Here we see a great difference between the pea and the wheat. Near the blunt end of the wheat is the germ, consisting of seed leaf, plumule, and radicle; all the rest of the grain is filled with the white substance, chiefly starch, which is the food that is to sustain the young plant until some other means are provided. This substance, starch, you will remember, is **insoluble in water**, becomes changed into a **white, sweet fluid** by the chemical action of the oxygen, which takes place during germination, and then becomes easily soluble in the water which penetrates the seed; and then, with the other food substances which have been subjected to the same action, it passes from cell to cell, till it reaches the young plant, and **supplies it with perfect food**.

We examine the seed again, and find it further advanced; we observe **three root fibers** coming forth from the **blunt end** of the wheat root, and, after awhile, again we see that the fibers have increased in number and length, which are now covered with tiny things looking like hairs; at the same time we find the plumule has advanced upwards into a **green shoot**. The plant is now ready to begin life on its own account. It can now **absorb nourishment** from the **soil**, and pass it on upwards to the leaves, which are now ready to do their appointed share of the work.

CHAPTER LIX.

GERMINATION OF SEEDS—PEA AND TURNIP.

WE may now observe the germination of the pea. The arrangement in this seed we find to be very different to that of wheat. In the first place, there is no separate store of food, as in wheat; but, instead, we find two thick, fleshy leaves filling up the hull or case, and shaped like hemispheres, which come apart; between these two leaves lie the plumule and radicle.

When it germinates, and the seed-leaves swell up with the moisture and the oxygen which enter the irrigating channels, the starch and other substances which they contain become sweet and soluble, and so pass through the cells to the plumule and radicle. These then begin to grow—the radicle growing downwards and the plumule upwards—until the tiny root-hairs appear, and the first green leaves spread out to the air. The young plant is now able to get food for itself, and has no further need for the seed-leaves, which perish underground.

There is another difference in the germination of turnip seed. The embryo, like that of the pea, has two seed-leaves, but they are small, and hold only a small supply of food. But **they push quickly** up into the air, throw off their seed-case, spread themselves out to the air, and become green, and begin almost **at once to draw in food** from the soil and the air, and thus make up for the very limited supply furnished by the seed.

Another difference in the turnip seed is that the store of nourishment consists chiefly of **oil**, instead of

starch; but you will remember that both substances are composed of the three elements, carbon, oxygen, and hydrogen, and that both can be changed by germination into a sugar-like substance. You will likewise notice that in the germination of wheat the radicle gives out several fibers from a sort of sheath or blunt end; while in the pea or turnip the **radicle itself elongates** and goes down into the soil, forming a "**tap-root.**" These are the principal modes of germination among all ordinary plants.

Barley, oats, rye, and all the grasses, germinate like wheat; beans, clover, and all the legumes like the pea; cabbage and mustard, like the turnip.

CHAPTER LX.

CONCERNING THE ROOTS OF PLANTS.

WE are now prepared to take up the subject of the roots of plants, and inquire into their uses in the economy of vegetable growth. The food of plants consists of various mineral matters completely dissolved in water in the soil, and of certain gases, especially carbonic acid gas, which exists in the air. We have likewise learned, in a former chapter, that the water carrying the food in solution passes through the hair-like membranes of the roots into the cells of the plant on its way to the leaves.

Let us now inquire how plant-roots go down into the soil. It cannot force its roots down into the soil as you would **force a stick into the ground.** The root **stretches down** into the soil by the **growth of new cells near the tips of the rootlets.**

The tip of the root grows into the little spaces it finds between the particles of soil, and then the **cells** just above the tip **multiply very fast**, by each cell dividing into two, each of which becomes as large as the first cell when it is again ready to divide; as this goes on in hundreds of cells, and these all become swollen with moisture, absorbed from the soil, the rootlet grows rapidly in length and thickness, creeping into the spaces lower and lower down into the soil, and making these spaces wider by forcing away the particles on every side. If the subsoil is very hard and close, and the fibers find no spaces to grow into, they either cease to grow, or spread out sideways among their neighbors, and thus, becoming crowded, they get an inadequate supply of food. One of the benefits of deep cultivation, you will perceive, is the loosening of the subsoil, thus allowing the tips of the roots to grow into it freely in their search for food.

The roots of some plants grow down to a great depth in their search for food. Lucerne, a kind of clover, has been known to send its roots more than fifteen feet in an open soil. Wheat and red clover also send their roots down to a depth of seven feet, if the subsoil is favorable; barley and grass spread out their roots **near the surface**; corn is a vigorous grower, and sends its rootlets far and wide, **but not deep**; they have been traced a distance of thirteen feet from the stalk.

The thick, fleshy roots of turnips and beets show a different economy to the plants we have been considering. They collect food from the soil, pass it upwards to the leaves, where nature's laboratory is located, and it goes back from the leaves in the form of sugar and other organic matters, to be stored up in the bulb until the second year, for the purpose of supporting the plant, while it is bringing forth **flowers and seeds**.

These kinds of plants are called **biennial plants**, because they require two years to complete the round of their existence. Roots possess the power of absorbing carbonic acid and ammonia, and of employing these in their organism in the same way as if the absorption had taken place through the leaves.



CHAPTER LXI.

USES OF STEMS—LEAVES, THE LABORATORY OF NATURE.

THE **stem** grows from the tiny plumule, or bud of the seed, up into the air. One of its important uses to the plant is to **lift up its leaves** to air and light; another use is to convey to the leaves **the dissolved food** which the roots have absorbed from the soil.

The stems of wheat are hollow, and have no branches; those of potatoes are solid and branched; while turnips and beets have very short stems **the first year** of their growth; the leaves seem to grow at that period from the top of the root; but all are built up alike of minute cells, some short and round in shape, others elongated and narrow, through which the sap passes on to the leaves.

The principal organs which **assimilate the food**, or make it like the substance of the plant itself, are **the leaves**. Stop here and consider the wonderful and important duties of a leaf. From the simple substances, water, carbonic acid, ammonia, potash, and the other substances given in a former chapter, are produced the complicated substances, starch and cellulose, of which the plant is built up.

The **leaf** is the **factory** in which this work goes on; therefore, if a plant be stripped of its

leaves, it cannot live. The exact chemical process by which these wonderful results are produced have, up to the present time, **eluded the search of man**; but the general process has been made out pretty clearly.

The leaf is composed of layers of soft green cells, strengthened with ribs consisting of long hard cells. These ribs are sometimes called veins, but they are **not hollow** like the veins of animals. The ribs strengthen the tender leaves, and convey sap from the stem. The upper and lower surfaces of the leaf consist of thin, transparent skins, having a great number of minute openings, like pores in the skins of animals, through which the carbonic acid and other gases are taken in from the air, and watery vapor and oxygen gas given out. This water and oxygen came up from the roots of the plant with what was held in solution; and as **they** are breathed out, the other **substances** which it contained **are retained** in the cells of the leaf, and are in some marvelous way assimilated by the help of the protoplasm and chlorophyl into organic substances, especially starch, with a small amount of mineral matter. From the starch, by the same mysterious agency, sugar, oil, and cellulose are formed. All these contain carbon, which is chiefly gotten from the carbonic acid of the air, so hurtful to man and animals; but the leaves give back to the air the **oxygen** which is so **beneficial to animal life**.

The substances composing the food of the plant having been thus assimilated by the mysterious action of the leaves, pass back into the stem from the leaves, and are used there at once, or are stored there or in the root for future use.

To accomplish this, mysterious chemical changes take place that we can only in part know. Take, for

example, a potato plant; starch is formed in the leaves, which substance is insoluble in water, and, therefore, in that state it cannot pass through the walls of the cells to return to the stem; a change takes place whereby the starch is made into a kind of sugar, which we all know is soluble; it then passes down the stem of the plant to side branches below the surface, where it is again changed back to starch, and forms the tubers (potatoes), for which the plant is cultivated. These tubers are really short, thick branches, filled principally with starch, and the eyes are merely buds.

In the turnip the same mysterious changes take place, only the store is deposited in the root, which thus becomes thick and fleshy.

In the beet plant the starch formed in the leaves changes into grape sugar; then it passes back down the leaf-stalk; then into the root, and there changes into cane sugar.

In wheat the assimilated materials in the leaves pass back to the stem, and then it passes upward and into the ear, to become fruit and seed.

You must remember there is no continuous system of vessels to carry these substances, as in the animal economy, but they pass from cell to cell towards any part of the plant, which, in active growth, requires the supply.

CHAPTER LXII.

THE FLOWER.

You may have observed that all plants with which you are acquainted have flowers; some are bright colored, and some dim colored—not easily seen; some are large, as the pea and the clover, and others small, as

those of the wheat, the grasses, and the beet. The flowers, however, whether large or small, are all **constructed** on the same principle, perform the **same functions**, viz.: They bring forth seed, and, therefore, increase and multiply their kind.

Suppose we take a few flowers and examine them, and see how they are constructed and fitted for the duties assigned them. You will be more interested if you do this, each one for himself, and try to make out the different parts of each flower you may find.

Take first the flower of the cabbage, the turnip, or the mustard, and you will see that they are all nearly alike. You may, perhaps, not be able to meet with either of these as conveniently as you can a **single wall-flower**, which is very nearly like them, and it is found in almost every garden. First, pull off the **four outside green leaves of the flower**, which form the calyx; next the **four bright colored leaves**, called the corolla, which, you will observe, are arranged in the form of a cross, from which fact the whole of these plants, and all others like them, are classed by the botanist in the order **cruciferæ**. These parts you have stripped off seem designed to protect the **inner organs**, and probably to attract insects, the use of which we shall examine hereafter; the inner organs are the most important parts of the flower. You will now see six upright stalks, called filaments, two of which are a little shorter than the rest—all having knobs at the top, called anthers, which, upon investigation, you will discover to be hollow, and bearing a fine yellow powder. These are called stamens, which consist of filament and anther. In the centre, surrounded by these stamens, is the **pistil**, which would, if the flower had been allowed to complete its course, become the **seeds or fruit**. Before this can

happen, however, it is necessary that some of the yellow powder, which is technically called pollen, **should fall upon the top of the pistil**, when it would penetrate to the ovules contained in the pistil; they are, **by this means**, caused to grow until they become perfect seed.

This action of the pollen is called fertilization, because it causes the plant to become fruitful, and bring forth seed and fruit.

CHAPTER LXIII.

THE FLOWERS OF THE PEA—WHEAT AND CLOVER.

SUPPOSE we now take the flower of a **pea**, and try to make out some of its parts. We find the colored part of these flowers to be of a peculiar **winged shape**, similar to the wings of a butterfly; therefore, plants of this family are said to be *papilionaceous*; they likewise form part of a large order of plants which **bear pods**; the order on this account are called *leguminosæ*.

In this flower you will find ten stamens, nine of them being joined into a tube-like vessel around the pistil. The pistil consists of one cell containing several ovules, which will increase in size and become the pea-pod with its peas.

In clover, upon examination, you will find a large number of flowers, similar to those of the pea, each having its stamens and pistil, but bunched together, forming what is called a **compound flower**.

We shall now examine a **flower of wheat**, because it will be a fair representative of the grass family. We must look for the flower when the leaves are very green. You will see many tiny yellow bodies hanging out of

each ear; these are the stamens. You will also find the ear to be composed of several rows of these tiny flowers arranged around a central stalk. Take one of these flowers; instead of bright-colored leaves, as in pea, clover, or wall-flower, we find the flower to be inclosed in small, **chaffy-like leaves**, having the stamens, with fine thread-like stalks and hanging heads surrounding the pistil, which has but one ovule. At the top of the pistil are two feathery arms which receive the pollen of the stamens, and convey it down into the pistil; the ovule is then said to be fertilized.

Corn has a somewhat different arrangement. The "tassel" at the top of the plant produces the pollen in great abundance, and in its season fills the air, and the "silk" projecting from the ear conveys it to the ovules; but on account of the distance between the "tassel" and the "silk," if a stalk of corn grows up with no near neighbors, but few of the pistils will receive the pollen, and the ear will, consequently, be found to have but few grains on it.

CHAPTER LXIV.

FLOWERS—THE REASON OF THEIR ATTRACTIVENESS.

You have many a time observed in a field of clover, or other kinds of plants having bright flowers, how active bees and other insects are flying from flower to flower, searching for honey, which they find secreted by the flower, and held generally at the **very bottom** of it. In trying to reach this sweet liquid, the insects brush against the **stamens** and get covered with the pollen. They carry this to the next flower, where some of it is rubbed off against the top of the pistil, thus insuring the fertilization of the ovule.

It has been proved by experience that most plants produce more and better seed when they have been fertilized with the pollen from another flower of the same kind, than if each flower had been supplied with its own pollen. We, therefore, have come to the conclusion that honey-gathering insects benefit the farmer greatly by insuring the cross fertilization of the flowers of such plants as need it; thus benefiting the flowers as much as the flowers benefit the bees by supplying them with the liquid sweets. This, in fact, seems to be the reason why so many plants have showy and attractive flowers, with a delicious smell, and sweet liquid, as all these qualities are very attractive to the honey-gathering tribe.

This law of nature bids us be careful not to grow plants of the same order contiguous to each other, if our object is to get seed from them for sowing. For example, if cabbages and turnips, which belong to the order cruciferae, be grown for their seed in adjoining plots, insects will convey the pollen of the one to the other, and the turnip will be fertilized by the cabbage, and the cabbage by the turnip. The seeds of both will then be rendered worthless for the purpose of growing a crop from them, as they will produce neither the kind of cabbages nor turnips we wish to grow. We once planted some early amber sugar-cane seed, which had been grown next to a "corn patch;" both belong to the order gramina; the result was we had neither corn nor sugar-cane. It looked well enough while growing, but when the time of harvesting came, the stalks were light, like those of corn, and almost worthless for the object for which it was planted.

Wheat and other plants with dull, inconspicuous flowers do not require the help of insects, because they are either plentifully supplied with their own pollen,

or the wind scatters and mixes the pollen among the neighboring plants.

You may also notice the fact, that when the ovule is fertilized the **gay-colored parts**, together with the **stamens**, having performed their functions in the economy of the plant, and being no longer needed, begin to wither, **decay**, and **drop off**. The pistil, with its ovules, however, enlarges, and brings forth the seed and fruit.

The seeds of the turnip, wall-flower, and other plants of the same family, are produced in a **double kind of pod**, which opens **below**, on each side, and has two rows of seed.

The fruit of the pea, and other leguminous plants, is produced in the well-known single pod or legume, with one row of seeds.

In wheat and other plants of the grass family the fruit is called the seed, because the covering or case fits it so closely that it cannot be taken off without destroying the seed. This outer covering is the bran which comes off in thin pieces when the grain is reduced to flour in the process of milling.

The **fruit** of the potato is the **green plum**—a fleshy fruit growing on the vine above ground, containing the seeds. They are of little importance to the farmer, as he produces his crop by planting the tubers, which are really short, thickened knobs of underground branches with buds.

✓ CHAPTER LXV.

HOW AGRICULTURAL PLANTS ARE UTILIZED.

THE whole object and aim of the entire life of a plant is to bring forth seed, thereby insuring the continuance of its kind through future generations.

We have spoken of the seed and its germination, and have come around to it again. All plant life seems to **round off in a circle**, and the farmer breaks into that circle at whatever point it suits his needs. Thus, when he wants the **green leaves** and stems, as he does in grass and clover, he encourages **green growth** by proper manures, and cuts them down when leaf and stem are at **their richest**. When he wants **the laid up stores** of the plants, which they put away for their own use, as he does in the case of the turnip and beet, he manures accordingly, and utilizes the crop at the end **of the first year**, when the plant has accumulated all the food it is capable of doing. When he wishes **the seeds**, as in the grain crops, he discourages the growth of **too much foliage**, and allows the plant to run the full round of its life, and cuts it down and secures it when its **seed arrives** at maturity.

You must bear in mind that the seed in all cases contains an accumulation of food both suitable and sufficient for the next year's young plant while in the process of germinating. Likewise, the seed, in many cases, makes excellent food for man and the animals used by him.

The farmer grows seed for two purposes, viz.: For food and for **sowing** again. By **selecting the seed** carefully, and **choosing the best** every time, he can **improve** both the **quality** and **quantity** of **his crops**, if the land be in proper condition. By continuing this process for years, we come **to establish** the good points of quality; such seeds are then called **pedigree seeds**. It was the carrying out of this **process of selection**, that all our cultivated plants were improved up to the standard of excellence we now find them, from the plant growing in **a wild**

state. By selection, wheat, rye, and oats have been derived from the **grasses**; cabbage and turnips from plants, even now growing wild in Europe; and the beet from the **worthless-looking sea beet**, which abounds on the seashores of England and Ireland.

It is important that the farmer should not overlook the fact that it is the same with plants as with animals. Development does **not eradicate constitutional traits and tendencies**; therefore, beneath all is the **craving** for the primeval condition of life, and so the best success with plants of any kind will assuredly be attained by those who can give them the **nearest approach to the soil, climate, food, and culture suggested by their native haunts and habits.** Wetness is not favorable to plants generally grown for a crop; but abundant and continuous moisture is an absolute necessity. Soil naturally deficient in this, and which cannot be made **drought-resisting** by deep plowing and underdrainage, is not adapted to growing crops. The beet still **craves** for the **briny spray** of the sea; the strawberry for vegetable mold; and the gooseberry for the cool shade.

CHAPTER LXVI.

AGRICULTURAL PLANTS AND THEIR BOTANICAL ORDER.

WE have now learned how crops grow; how seeds germinate; how nourishment is collected by the plant; how plants bring forth seed, and thus reproduce and multiply their kind. It will be well now to learn **how crops are grown**, so as to produce the **greatest quantity** of food in the **best condition** for man and beast, with the **least labor and least**

expense to the farmer. The crops may be classified as **grain crops, fodder crops, and root crops.**

It may be of interest to state, that out of the many orders of plants which are found in the United States, **six orders** contain nearly all the cultivated plants grown on the farm generally for a crop; and the greatest number of these are confined to three great families, viz.: Grasses, legumæ, and cruciferæ.

The six natural orders are these: (1) Gramina, or grass family, such as wheat, corn, oats, barley, and rye. (2) Leguminosæ, or pod-bearers, as clover, beans, peas, and vetches. (3) Cruciferæ, or cross-bearers, as turnips, mustard, and cabbage. (4) Chenopodeæ, or spinach family, as the beet and celery. (5) Umbeliferæ, having umbel flowers, as the carrot and parsnip. (6) Solaneæ, or nightshade family, as the potato, tobacco, and tomato.

The word cereal is derived from the Latin word *Ceres*, which was the name of a heathen goddess, who was believed by her worshipers to preside over the interests of the agriculturalist. Crops which are chiefly cultivated for **their seeds**, as wheat, corn, oats, and rye, are called cereals.

Of all the cereals, **corn** may be set down as the most important. If the farmer should be successful in procuring a good crop of corn, although every other crop should fail, he may be considered in a comparatively comfortable condition. "Famine begins at the stall." There is no fear of such a crisis if the corn crop be abundant, because it is valuable both for fodder and grain. It may be considered **the sheet-anchor of the farmers of the United States.** Just stop for a moment and think of the marvelous wealth coming from the corn crop of the United States. Upon an average of one hundred days from the time the seed is

planted till the grain is matured, its production has a money value of over \$600,000,000, averaging over \$6,000,000 daily of actual wealth each day of its life. No other product from any other source in the Union can compare with it. And think again, that **with proper tillage, without increasing the acreage, or very much augmenting the labor, the crop may be doubled.**

There are many varieties of corn, which have been developed by careful selection of the seed and by growth in different localities and climates. Some kinds are peculiarly adapted to **short seasons**, and others to **longer seasons**. The best soil for corn is a rich clay loam; but it will grow with fair success upon any moderately fertile soil, where the climate and variety of seed is suitable in the United States. There is no crop responds better to deep cultivation and frequent stirring of the soil while the plant is making growth. If the stalk and leaves are designed to be utilized for fodder, it must be cut before frost affects it, carefully cured, and protected from the elements. There is no food better relished, nor more healthful for all kinds of stock, such as horses, cattle, and sheep. Ailments arising from the use of corn fodder are unknown, if it has been well cured and protected from the weather. Let the same care and labor of storing be employed in providing the winter supply from this plant, as for ensilage, and it will give more satisfaction and cost less, with no risk, than the silo can possibly be expected to do in our dry atmosphere. Corn was unknown to the people of the Old World until the discovery of America by Christopher Columbus in 1492.

CHAPTER LXVII.

THE WHEAT CROP.

THE next cereal in importance is **wheat**. It is most probably a native of Europe, or Southwestern Asia, but it has been cultivated for very many years in **every country of the world**. By careful selection, many kinds have been produced, such as the white and red wheat, the smooth and bearded, and the winter and spring wheat. It is the habit of wheat to **penetrate deeply into the soil** in search of food. The best soils for wheat are the **reddish clay** soils of timber land and a **clay loam**. The wheat raised on timber land is generally plumper in the berry, smoother, brighter, and thinner skinned than that grown in the prairies, and brings the highest price.

The usual order of wheat, in the rotation of crops, is after clover. The clover is turned under and the wheat drilled amongst its inverted roots, which gathered their nourishment from the subsoil, and gives that firmness to the seed-bed which wheat requires without allowing it to become baked.

When the seed has germinated, and the root-fibers grown out from the sheath, little buds sprout out around the young plant, and several stalks grow up. This is called tillering usually; in the Western States it is called "stooling out." As many as **forty stems** have been known to tiller out from one seed in good soil, and having plenty of room.

Wheat for milling purposes should be cut as soon as the milky juice in the grain **sets firm**, so as not to

run out between the fingers when squeezed. If it be allowed to remain until ripe, it is liable to "shell out" when harvested, and the hull, or bran, becomes **thickened**. After the fertilization of the flower the plant **takes little or no nourishment from the soil**. The growth of the seed is due to the movement of the substances **already in the leaves**. These substances move up the stem and into the grain, and these movements go on just as well after the wheat is cut.

In manuring for wheat, it is best to apply **slowly-acting manures** to the previous crop. If the plant is not sufficiently vigorous in the spring, a top-dressing of a stimulating character, such as nitrate of soda, or a mixture of guano and bone meal, may be applied to encourage growth for a time, after which the energies of the plant should be devoted to filling and ripening the seed. If the growth be too vigorous, an application of between two and three hundred weight of common salt per acre will be found beneficial, as it discourages its too luxuriant growth. The average crop in this country is very low, being less than ten bushels per acre; but, by **proper cultivation and intelligent management**, the average crop may be raised to twenty-five or thirty bushels per acre, if the season be fairly propitious.

CHAPTER LXVIII.

BARLEY, OATS, AND RYE CROPS.

THERE are several varieties of barley—the two-rowed and four-rowed. That mostly grown is the two-rowed, or spring variety. It should be sown as early in the spring as possible. Great care must be taken to have a good **powdery seed-bed**; but it need not be so firm

as for wheat. The roots of barley spread out **near the surface** of the soil. For malting purposes the crop must be dead ripe before it is cut.

So great is the difference of barley in value for malting, that the kinds sold for feeding purposes are worth in the market only fifty or fifty-five cents per bushel; while that for brewing purposes brings more than a dollar per bushel. For malting, the best is grown in Northern localities, where the ripening process is gradual, slow, and complete. Hot climates grow barley suitable only as food for stock. Herodotus is credited with the statement that the people of Egypt, being without vines, "made their wine from barley." Pearl barley is the grain decorticated, and is principally used for making Scotch broth. Sick persons have been successfully brought through a fever by the cooling and nourishing diet of drinks made from pearl barley.

As we travel along a road in early summer, and look over a field of growing barley, and notice the soft, silvery sheen of the light and shade, which seems a visible song, as the breeze passes over the silky, green, and waving surface, so charming is this sight that the wanderer invariably stops, pausing in his walk to view the undulating picture. The pause is involuntary—much the same as when a rambler in the time when the

"Genial spring, wi' balmy breath, gars verdure spring anew,
And ilka blade o' grass kep its ain drap o' dew,"

hears the song of birds in a cosy grove, as his sense of hearing first catches the sound of nature's joyous choristers. In either case, the sense of sight or hearing derives a pleasure which, to be fully enjoyed, commands a pause beyond the ordinary emotions of life.

A **change of seed** is beneficial; that is, seed should be obtained from a crop grown in a **different district**,

as it has been found to succeed better than that taken from a previous crop on the **same farm**. This is proven to be **true of all cereals**. Experience taught us this very important truth. The average crop of barley is nearly twenty bushels; but, by proper tillage and good management, it may be raised to double that quantity.

The oat crop is one of the most hardy of the cereals. It is the chief cereal of Scotland, where it is grown to great perfection. The oat has its flowers and grain hanging from little stalks which branch out and around the main stem. More seed per acre is required for this grain than either wheat or barley, because it does not tiller so much as either of these.

Oatmeal forms an important part of the food of the yeomen of Scotland. Upon this fact Dr. Johnson based his definition of oats. "Oats," he says, "food for men in Scotland—in England for horses;" intimating that the Scotch fed on the kind of food which the English only fed to horses. But the Scotchman, it is generally considered, got the advantage of the doctor's sneering definition by appending the humorous finish to it: "And where find **such men**, and **such horses**." Although Sydney Smith said it required a surgical operation to get the point of a joke into the head of a Scot, yet it may be granted that he has some humor, which, when employed by him, is very caustic and complete.

Oatmeal contains more fat and more nitrogenous substances than wheat, and is proved to be the very best food which can be used for children and persons having to work in exposed situations in a cold climate. By analysis it is found to be the **best balanced food derived from any of the cereals**; that is, it requires less animal food to make up any

deficiency it may lack than bread made from wheat, which requires much animal food to make up and complete the balance of the nourishing substances necessary for the body.

Oat straw is more valuable than that of any of the cereals as a fodder, being often as nutritive as hay, especially if cut before it is quite ripe.

The average crop is about thirty-five bushels to the acre; but sixty or seventy bushels may be grown by good tillage and propitious weather.

Rye is also a hardy kind of grain, and may be grown upon poor, sandy soils, which would produce very little of anything else. It is often grown by farmers for green cutting and for a temporary pasture. Rye flour makes good, healthful bread, which is highly esteemed by the peasantry of Germany. It produces about thirty bushels per acre; but the production may be greatly increased by deep and thorough tillage.

CHAPTER LXIX.

THE MANAGEMENT OF THE HAY CROP.

WE now come to the grasses grown for their herbage. There are many kinds of grasses indigenous to the land in the United States. It is now a well-established fact, that while the **flowering stems are shooting up**, every species of grass **abounds with saccharine matter**; but, as the seeds approach to ripeness, the **sugar is converted into woody fiber**, while the gluten goes to form the seed. From this fact we arrive at the conclusion, that all grasses intended for hay lose their nourishing qualities if **permitted to form their seed**. By the digestive organs of ruminating animals the woody fiber is supposed to be reconverted

into the substances from which it was formed, and thus becomes nutritive. Boiling food for cattle is also considered an **unnecessary** and **profitless labor**, because of the digestive organs being capable of cooking the food in a manner more suitable to the ruminating animals' requirements than can be done by the art of man.

The proper time to cut meadow grass for hay is, undoubtedly, while it is **in bloom**, as the saccharine juices are then most abundant. If the cutting be delayed, the grass becomes withered at the bottom of the stems; the roots are thus injured, the after-growth is very much lessened, and the **land greatly impoverished**.

The great object to be attained in this work is, to have the hay preserved in the condition as nearly **like the grass as possible**, using great care in having it retain all its soluble matters in their completeness. In the process of making hay it will be of advantage to pay particular attention to the following points:

(1) Preserve as much as possible from **rain and dews**; for the soluble matters are easily washed out of hay.

(2) Do not disturb it in wet weather; alternate wetting and drying makes hay worthless.

(3) Scorching destroys its **virtues, fragrance, and color**, and causes it to become woody and brittle.

(4) It is necessary that the hay be dry, to prevent heating; the sugar is then changed into alcohol and carbonic acid, which may be detected by an odor coming from the stack resembling that from a brewery.

Ensilage is grass or provender of any kind preserved in a green state with all its juices complete. The green plants are generally chaffed, and placed in an air-tight pit or building, called a *silo*, and are packed down

solidly, as they are being put into the pit, layer by layer. The ensilage is then covered tightly with boards, upon which a heavy weight is placed. The most convenient weights for this purpose are empty barrels, so arranged as to distribute the weight evenly, and then fill them with water.

The chief point aimed at in this process is to **completely shut out the air**, with its oxygen, to prevent fermentation.

The utility of the *silo* to the practical farmers of the United States is, to say the least, **very doubtful**. It may be safely left to amateur farmers to experiment with, **who do not farm for profit**. The farmer who will bestow **as much labor and expense in sheltering his fodder from the weather** as he would have to do in filling a *silo*, will be amply rewarded with the results. In Great Britain and Ireland it may prove valuable to the farmers, because of the difficulty they experience in drying the hay in their **dropsical atmosphere**; but with the **dessicating air** of this country, the conditions are quite different.

CHAPTER LXX.

CLOVER-HAY AND THE SHELTER OF YOUNG GRASS.

Clover is an important fodder plant. There are several kinds, such as the red clover, the white clover, the Italian or crimson, the Swedish or Alsike, and the giant clover. A mixture of grasses and clover is frequently sown for pasture, or to be made into hay. Red clover is grown to precede wheat; its roots go deep into the soil, and bring up valuable plant food.

The roots have a most excellent effect upon the mechanical texture of the soil; binding its particles together, if too loose, and separating them, if too close; thus giving **firmness without hardness**—a condition so needful for the roots of wheat. The manure, also, from animals feeding on clover hay is **nearly double the value** for the land as that from timothy hay. We do not generally recognize the full value of this crop in its advantages to the soil. The time is approaching when the proper cultivation of the clover crop will be recognized as one of the greatest importance for the successful and profitable cultivation of the soil.

Clover hay is made in the same way as grass; but great care must be taken not to shake or handle it much after it is dried, as the leaves are then very brittle, and much of the fodder may thus be lost.

Before closing the subject of grasses, we may give a successful experiment made by an English farmer, which contains some valuable information. He observed how freely vegetation is continued through the winter or early spring when the surface was shielded by any loose material lying upon it. He found that if a board, or any other loose material, was supported within an inch of the surface, an increase of growth resulted. Straw, bushes, or any other similar material, produced the same result. Wheat straw applied over young grass, at the rate of about a ton or a ton and a-half per acre, in a very short time will increase the growth of grass to a wonderful extent.

One of the experiments was as follows:

COVERED LAND.	UNCOVERED LAND.
Produce Per Acre.	Produce Per Acre.
Grass cut May 15.....5,870 pounds.	2,307 pounds.
Clover cut June 2.....3,460 “	960 “

An increased number of experiments tended to confirm the preceding results.

We may give another example showing the beneficial effects of shielding the soil, when the young clover plant is growing, from the fierce rays of the summer sun. Frederick Tepe, of West Elizabeth, in Allegheny county, Pennsylvania, became the owner of a piece of land near that place which had been plowed and cropped by its previous owner until its producing power was gone. The land was hilly and the soil a stiff clay overlying limestone. The seeds sown would germinate well enough; but the **hot rays of the sun killed all the vegetation** on the land. Mr. Tepe set about preparing this land for a crop, and labored diligently to obtain a good seed-bed. His neighbors kindly tried to dissuade him from the attempt, assuring him that it would grow nothing; and, nodding their heads to one another, pitied "the foolish Dutchman." He heeded them not; he had faith in all he was doing; and, with the patience and tenacity of purpose characteristic of his nation, he kept on in the even tenor of his way. When he was ready, he sowed his clover seed, and afterwards began collecting all the straw he could find, which he **spread thinly but evenly over the field**. This shelter to the young plant proved to be sufficient, and he was rewarded with a **generous crop of clover** and the **restoration of his land to a fertile condition**.

CHAPTER LXXI.

IMPLEMENTS FOR HARVESTING CROPS.

LABOR-SAVING implements for securing crops are very numerous. Those of American contrivance and

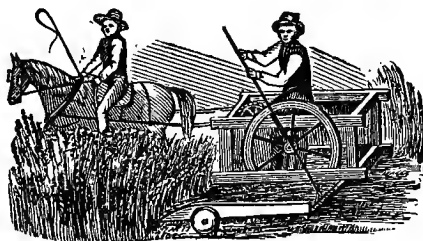
make are famed the world over for their excellence and adaptability to perform well the work for which they are designed.

The limits of this work will not permit us to enter into the subject to the extent we would desire. We shall, however, devote a chapter or two to the history of the "Reaper and Binder" machine, because of its being entirely the **invention and production of American farmers and mechanics**, and also because it is the one labor-saving machine which has made it possible for the farmers of this country to compete successfully in the economical production of wheat with all the nations of the earth.

Every nation which rose, or has risen, to importance since Rome was mistress of the world, has experimented with machines for reaping the cereals, but never succeeded in making a practically useful one. To **Cyrus Hall McCormick**, of Rockbridge county, Va., and **Oden Hussey**, of Baltimore, Md., belong the honor of producing the **first practically useful mowing and reaping machines in the world**. From these all reaping and mowing machines of the present day are evolved. The father of McCormick was engaged for several years experimenting with a reaping machine of his own invention, and tried it on his own wheat crop. This machine was pushed along in front of the horses, like the Scotch machine of Bell, which was brought out in 1826. McCormick improved on his father's inventions, and brought out a machine about 1833 that had the following features: (1) The horses were in front, and the cutting apparatus projected at the side. (2) The cutter was a reciprocating straight sickle, moved laterally by a crank. (3) Fingers projecting forward supported the grain while being cut. (4) The standing grain was leaned to the sickle

and finger-bar by a revolving wheel. (5) The grain was received on a platform, and raked from there in bundles. (6) A divider at the extremity of the finger-board separated the grain to be cut from the standing portion. Nearly all these features were original in this machine. The first public trial of reaping machines was made in the neighborhood of Richmond, Va., in 1843, between the McCormick and Hussey machines, the only practically useful reaping machines then in the world.

Through the kindness of a friend we are enabled to present to you a drawing of the original Hussey machine. The merits of these machines were very quickly recognized, and were without competitors for several years.



THE ORIGINAL HUSSEY REAPER.

The restless spirit of enterprise and advancement inherent in the American breast at length was turned to consider the faulty points, such as the unbalanced side draft, the narrow swath, the galling weight on the neck, and the heavy draft, which, in a few years, were all remedied by several inventors. The machine, thus improved, did good work; but it was faulty in its economy; it required one raker, generally seven or eight binders, two shockers, and one driver, to secure about twelve acres per day. Think of the great labor to the

farmer's wife, and the expense of feeding all these hands through harvest.

CHAPTER LXXII.

THE REAPING MACHINE.

LESS **manual labor** to secure the harvest became the necessity of the day. One inventor produced a reaper which cut off the heads of wheat with a few inches of straw. It was called a header. But it proved to be wasteful, and was entirely inoperative in tangled and reclining grain, and was soon generally abandoned. Another brought out a self-raker, which was successful, so far as the saving of one hand was concerned. Another made a machine which carried the binders, and, by an ingenious contrivance, the wheat was brought to the two binders, where they stood on the platform attached to the machine provided for that purpose, who were sufficient to do the binding, thus making a greater saving in labor than any preceding reaper. We cannot wonder that the farmers considered this machine, at that time, **perfection**. The restless spirit of the inventors, however, were not yet satisfied; the investigation was continued, and, after much thought and labor, their efforts were finally crowned with success; and they have now brought out machines which both reap and bind the grain better than it was ever done by hand; and, by them, the necessity of manual labor was reduced to the minimum. One man with a team of horses can reap and bind with this machine from fifteen to twenty acres each day.

The material at first used for binding was wire; but it was objectionable for two reasons: (1) In threshing the grain some of the wire was broken into small pieces

by the thresher, and got among the straw, which proved hurtful to the stock which fed at the straw stack in winter. (2) Small fragments of the wire also got amongst the grain as it came from the thresher, which caused much annoyance to the miller by getting between the burrs. These faults were completely overcome by changing the binder, so as to use cord instead of the wire.

The farmer can now procure a reaping and binding machine which will do satisfactory work, and reduce the cost of harvesting to the lowest point possible, if he exercises skill in selecting it, and afterwards in its management.



CHAPTER LXXIII.

IMPORTANT POINTS OF ECONOMY IN A MACHINE.

IN reaping machines, as in every other implement for use on the farm, there are some superior to others. In selecting a machine the farmer should be careful to see that it is adapted to the land upon which it is to be used. If his land be hilly and uneven, a low-down binder may serve him best, because its centre of gravity is nearer to the ground than one whose works are high, and is, on this account, less liable to tilt on the hillside, and will also operate with less strain of the gearings on an uneven surface. If, on the other hand, his land be level, he may choose an elevator binder, with a breadth of cut suitable to the horse-power at his command.

It will be to his interest also to satisfy himself upon the following essential points of the machine at the time he selects it:

(1) That the best material in every part of its construction has been used, bearing in mind that the weak part of any machine determines the strength and durability of the whole.

(2) That the mechanical principles are correct, and the workmanship, to the minutest detail, is well done. Correct mechanical principles produce simplicity, and minimize friction.

(3) That the cutting apparatus, and the machinery to take the grain to the binder, is suited for the work.

(4) That the gearing is well protected from mud and straw.

(5) That the knot-tying apparatus is durable and exact in its work.

(6) That the machine can make bundles, **any size desired**, automatically.

(7) That it can be **adjusted** to suit short or tall grain without waste.

(8) That the machine is well-balanced throughout.

There are other points of economy worthy of the farmer's attention—for example, in the quantity of cord used in binding, and the amount of travel required to do a certain amount of work.

The cord, when around a bundle, takes the form of a circle; the saving in twine, by a machine which binds a **certain sized** bundle, over one which binds according to the **space traveled**, without regard to the **close** or **scattering** condition of the stand, will be made evident when we solve the following problems:

(1) How much more water will flow from a pipe with an opening one inch in diameter than from a pipe one-fourth inch in diameter? Answer. Sixteen times as much.

(2) How much more wheat can a string bind which makes a circle having a diameter of two feet than a string having a diameter of one foot? Answer. Four times.

(3) If horses have to travel two hundred miles to cut one hundred acres, with a machine cutting four feet

wide, how far will they require to travel to cut the same number of acres with a machine cutting five feet wide? Answer. One hundred and sixty miles.

(4) If, in twenty-four miles travel, a machine cutting four feet wide reaps twelve acres, how many acres will a machine cut in traveling the same distance reaping five feet wide? Answer. Fifteen acres.

If a farmer selects a reaper and binder, in which the above points of quality and economy are combined, he will be relieved from much vexation, and derive both pleasure and profit; even if he had to pay more money for it, at first, than for an inferior one, it was economy to do so.

We cannot close this chapter without noticing the mowing machine, which also has been greatly improved in late years, and is a valuable labor-saving machine.

A few years ago many deplorable accidents happened to the drivers every haying season, when the cutting apparatus was placed behind the driving-wheel, by being accidentally thrown from the seat, and falling in front of the knives. The seat of the driver is now placed in the rear of the driving-wheel, and the cutting apparatus to the front; consequently, if the driver should be accidentally thrown from his seat, he falls behind the knives, and the deplorable result is avoided.

CHAPTER LXXIV.

SOME OF THE PESTS OF THE FARM.

WE will now consider some of the enemies of the farmer, which injure his crops. The **animal** and **vegetable kingdoms** bring forth pests, which require the farmer to be on the alert and wage constant

and unceasing war with them or they will frustrate every endeavor of his to make farming pay.

Weeds and **fungi** are his vegetable enemies. As dirt is matter out of place, so a weed is a vegetable growing in the wrong place. Weeds require light, air, and plant-food; therefore, if they grow with the crop, they become competitors for all these things; and as weeds are generally stronger, broader-leaved, and longer-rooted than the plants of the crop, they are able to overcome them, and cause them to become **weak, sick, and worthless**; in short, **weeds are robbers**.

Some weeds tell the farmer by their presence that the soil is thin and poor, as wire-grass and pennyroyal; others, that the land needs lime, as sorrel; others, that the soil is wet and requiring to be drained, as rushes, sedges, and buttercups; while others tell the people who pass that way that the occupant of the land is lazy and thriftless, such as the nettle, the dock, the jimson, and the thistle. Weeds should never be allowed to ripen their seed. They should be cut down or uprooted at once. The weeds, against which the farmer has to war, form a very large army, and belong to different families.

Fungi are plants of the same order as the mushroom, but they are so small that we can only see **their individual form** by the microscope. **Mould, mildew, smut, bunt, and rust** are simply fungi. Mould and mildew form dark spots and rust red spots on the plant, which cause it to sicken, droop, and die; bunt and smut fill the ears of wheat and other cereals with a black powdery substance in place of the grain. Fungi are generally encouraged by **damp** and **shade**. The seed of wheat is generally steeped in a **weak solution** of the sulphate of copper (blue vitriol) before sowing, to rid it of **fungi spores**, which may be attached to it from the previous crop.

Land subjected to a **good rotation of crops** is kept comparatively clean, and the labor of the farmer is greatly lessened in clearing his land of weeds by a judicious course of crops.

CHAPTER LXXV.

THE INSECT PESTS OF THE FARM.

THE great majority of the animal pests of the farm are insects. Birds do a great deal more good than harm. In places from whence birds had been banished insects increased, and the birds are now universally protected and encouraged to remain.

The cut-worm is very destructive to young plants; it is the grub of the fly known generally as the "jenny spinner." It is best to push the young plant by giving it a stimulating fertilizer, such as guano, or any nitrogenous manure, to get it past the period when its young roots are just beginning to get food from the soil. The wire-worm is one of the most destructive of all the insect tribe, as it lives several years in the soil, and destroys the roots of every kind of crop. It is the grub of the small "click beetle," so named from its ability to right itself by making a spring with a sharp click when turned on its back. The grub is stiff, hard, and shiny, like a wire; hence its name. It has three pairs of legs near the head. By these six legs it is distinguished from other grubs, such as the thousand-legged grubs, which do no harm. After they have fed on the crops for three or four years, they change their state and come out "click beetles." The most effective remedy is deep cultivation and applying the heavy roller in the spring.

The turnip flea is the most destructive insect to turnips and young cabbages. They are little, shiny black beetles, having strong wings and legs, and can hop a long distance; hence their name. They feed upon the young seed-leaves of cabbages and turnips. When none of these plants are convenient, they feed upon others of the same family growing wild about the fences. Thus, again, we are reminded of the need of cleanliness in every part of the farm, the keeping down of weeds, and the clearance of every waste matter from the fields. A good moist seed-bed and a stimulating manure will enable the plant to get out of their way.

The "chinch" bug is probably the most destructive insect to the wheat and corn crops in a large portion of the Middle and Western States. These insects appear early in spring, and are sometimes found in myriads at the junction of the stem and root of the young wheat. They first appear as wee, tiny mites, when they are of a reddish brown color; they afterwards grow darker, and then mature to a brown-like midge. When bruised they give forth a very offensive odor, like the insect generally known as the bed-bug; hence their name. Before they get wings they are very destructive to corn and wheat by feeding on their juices. We have seen whole crops rendered nearly worthless by these pests. No remedy has yet been discovered to stop their progress when they have once taken possession of a crop. They are found wintering among the blue grass in the hedge-rows, and among leaves and straw. Here again we are reminded of the necessity of thorough cleanliness all around the fields, and the advantage of a wire fence, which, we believe, is destined to become the fence of the future.

Many other causes, as well as the pests we have named, render farming unprofitable—some of which

may be summarized as follows: Not understanding the business of farming; insufficient capital for the number of acres farmed; extravagance in personal expenditure; buying on credit; not suiting crops to soil and climate; too many weeds; too little hoeing; too shallow cultivation; too little purchased food; using antiquated and improper implements; insufficient shelter for live stock; too little experience and too much prejudice; selling produce on credit to unsafe persons; carelessness in the selection of seeds; being behind in tillage, sowing, and the general work of the farm; and not taking and reading a reliable agricultural paper, or any literature on the subject of his business.

Finally, by deep and thorough tillage, and drainage where necessary; a judicious rotation of crops; a wise selection of ripe, clean, and healthy seed, suitable to soil and climate; clearing the land completely of weeds, old straw piles, and rubbish of every kind, and giving them back to the soil as a manure; the judicious application of manure; the careful management of the barn-yard manure heap, and **never over-looking he wants of a crop** from the time it is put into the ground till it is harvested, the farmer may expect, with almost **absolute certainty**, to realize pleasure and profit, and secure the blessings of Ceres, as expressed in the inimitable language of Shakespeare:

“Earth’s increase, foison plenty,
Barns and garners never empty,
Vines with clustering bunches growing,
Plants with goodly burthen bowing;
Spring come to you at the farthest
In the very end of harvest!
Scarcity and want shall shun you,
Ceres blessing so is on you.”

CHAPTER LXXVI.

MISCELLANEOUS.

VENTILATION, DURABILITY OF TIMBER, WEIGHTS, AND MEASURES.

ALTHOUGH the construction of farm buildings does not come within the scope of this work, we shall venture a suggestion on the very important subject of ventilation, the value of which cannot be overestimated. Men and animals absorb oxygen from the atmosphere, and give off carbonic acid. Plants absorb carbonic acid and give off oxygen. That which would be death to the one gives life to the other. The health of ourselves and our animals requires a system of ventilation which permits the carbonic acid to escape. To destroy the equilibrium of the atmosphere in a building, and then control its efforts to equalize, are the objective points to be reached, in order to obtain a plentiful and healthful supply of air. There can be no robust health enjoyed by animated beings where the air is stagnant; and, on the other hand, the health of animals is endangered if they be exposed to drafts of air; therefore the necessity for procuring the admission of fresh air and the egress of impure air without a perceptible draft.

Farmers in building a barn, as a general rule, believe that they have secured a sure and reliable ventilation by an elevation in the roof, whose sides have louver boards to keep out the rain, and admit air freely. Let those who believe that they have thus accomplished the task go up and examine, and they will find that the

wind passes straight through, while the air below the bottom board of his ventilator is stagnant. But let him put in a dividing-board, or partition, extending vertically from the top to about one foot below the lowest opening of the ventilator, and the change will astonish him. On the one side he will feel the cool air coming in and descending, and on the other side he will feel an ascending current of impure air making its escape. No such action takes place in an undivided opening, and no such ventilation is secured without draft.

DURABILITY OF TIMBER.

The durability of timber is also of much importance to the farmer. A few observations on the subject may not be out of place. All plants consist of two substances—the one cellular, the other fibro-vascular. The former is composed of roundish cells, the latter of long tubes; both are termed tissue by physiologists. The cellular tissue is brittle, like the pith in the elder; the fibro-vascular is tough and strong, as in hemp fiber. Timber consists of these two tissues intermixed, and when it grows slowly is more cellular than fibro-vascular. There is never expansion of the fibro-vascular parts; their aggregate number is only increased. For example, suppose a stick an inch in diameter to contain five hundred tubes; if the conditions for its growth had been so favorable that it had grown twice as fast, it would not have expanded those tubes, but would have added five hundred more; therefore, fast-grown timber is not weak because it grew quickly, and it would not have been stronger if it had grown more slowly. Spring felling of timber, especially of deciduous trees, is highly injurious to the durability of the lumber; for the tree is then full of sap, which makes the process of seasoning not only very tedious, but, when dried, the

germs of fungi find the conditions in it very favorable for their development, and cause decay, which is known commonly as "dry rot." Durability depends greatly on the time of felling the tree, the kind of soil on which it grew, the nature of its growth, and general management. Pruning, early and judiciously performed, will increase the quality, dimensions, and ultimate value of the tree. Thinning will insure "the survival of the fittest."

WEIGHTS AND MEASURES.

In England the unit of all weights was originally a grain of wheat taken out of the middle of the ear and dried, thirty-two of which weighed a silver penny; the pennyweight was afterwards divided into twenty-four equal parts, still called grains. There are 5,760 grains in a troy pound, and 7,000 in an *avoirdupois* pound. A cubic inch of rain-water weighs 252.458 such grains, when the temperature is sixty-two degrees by Fahrenheit's thermometer and the barometer thirty inches.

In measuring lines, the brass rod made by Bird in 1760, now in the custody of the clerk in the House of Commons, in England, is the standard from which all the lineal measures are taken in this country. It is thirty-six inches in length, each inch being the $39\frac{1}{4}$ part of a pendulum vibrating seconds of mean time in a vacuum at sea-level, with the thermometer at sixty-two degrees and the barometer thirty inches. It is a remarkable coincidence that a pendulum vibrating seconds corresponds almost exactly with the French metre. If all the standards of weights and measures were lost, they could be restored by the pendulum vibrating seconds under the above conditions.

The standard measure of capacity is a vessel holding ten pounds (*avoirdupois*) of rain-water, which contains

one gallon, or 277.2738 cubic inches. The gill weighs five such ounces, and contains 8.6649 cubic inches.

Farmers wish sometimes to know how many plants, or corn hills, or trees an acre will contain when placed certain distances apart. The process of finding the number is easy. Multiply the distance one plant is from another in the row by the distance between the rows, and divide the area of an acre by the product; the quotient will be the number sought. Suppose we wish to know the number of plants in an acre, the plants being placed one foot apart; or the number of corn-hills, placed three and a-half feet apart; or the number of trees, placed thirty feet apart in the rows, and forty feet between the rows. The answers will be found as follows:

Square feet in
an acre.

$43560 \div (1 \times 1) 1 = 43560$ plants in an acre set one foot apart.

$43560 \div (3\frac{1}{2} \times 3\frac{1}{2}) 12\frac{1}{4} = 3555$ corn hills in an acre set $3\frac{1}{2}$ feet apart.

$43560 \div (30 \times 40) 1200 = 36$ trees in an acre set 30 feet from each other in the row, and the rows 40 feet apart.

GOVERNMENT LANDS.

The lands of the United States are surveyed into rectangular portions, bounded by lines running with the cardinal points of the compass.

A parallel of latitude and a meridian are first established. Lines are then run six miles apart each way, which division constitutes a township, and contains generally thirty-six square miles. A line of townships extending north and south is called a range. Ranges are designated by their number, east or west of a certain principal meridian. Townships in each range are designated by their number north or south of the parallel of latitude, called a base-line.

Townships are sub-divided into sections, half sections, quarter sections, half-quarter sections, and quarter-quarter sections.

Diagram No. 1 shows the sub-division of a township into sections, and how they are numbered.

Diagram No. 2 shows the division of a section, and how they are designated.

A township equals six miles by six miles=thirty-six square miles, or 36,000 acres.

A section is one square mile=640 acres.

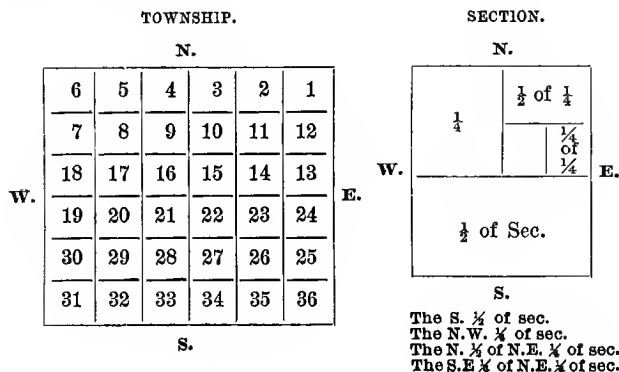
One-half section.....=320 "

One-half of $\frac{1}{2}$ section..... 160 "

One-half of $\frac{1}{4}$ "= 80 "

One-quarter of $\frac{1}{4}$ section.....= 40 "

The earth's surface is convex. The principal meridians, therefore, converge as they extend northward, which tends to throw townships and sections out of square, and necessitates occasional lines of offset, called correction lines.



QUESTIONS IN THE FIRST DIVISION.

QUESTIONS ON THE PLANT.

WHAT is the meaning of the term Agriculture? Give its derivation. Give the derivation of Horticulture. What sciences aid farmers in their business? What knowledge does each of these contribute? Do plants obtain all their food from the soil? From what source do they obtain the rest of their food? Describe a root and tell its uses. Describe a stem and give its uses. How does a plant take in nourishment? Describe a leaf. What is a potato? When do flowers appear on a plant? Describe a flower. What is organic matter? What is inorganic matter? Can a plant be grown to perfection without putting it into the soil? Tell how you would do it. What three things are necessary to enable seed to grow? Describe a seed. Can solid substances be dissolved in water? Give familiar examples. How can you prove that one kind of liquid, although separated from another by a thin membrane which has no hole in it, pass through the one into the other? What is the most abundant substance in a growing plant? What per cent. of water is in grass? In turnips? In cabbage? Is water in a plant stationary? Describe its passage through the plant, and how it gets out of the plant. Tell what you know about starch, sugar, oil, cellulose. Are these substances interchangeable—that is, can starch become sugar in the plant? Tell us in what plant starch becomes sugar, and again changed back into starch. What is protoplasm? What is chlorophyl? Give the derivation of these words. Of what elements are they composed? Why are these substances called organic?

SECOND DIVISION.

How can you separate the organic and inorganic substances composing a plant? Which part goes off in the air? What becomes of the other? From whence were the organic substances derived? From whence the inorganic? Name the ele-

ments composing each. What is the composition of pure air? What other substances are generally mixed in it? What is the chief duty to a plant performed by water? How can mineral substances be taken by a plant? Do plants feed direct upon the offensive matter put into the soil? Of what use is it then? From whence did the soil come? Give its history. Describe the first soil that appeared on the earth's surface. Tell us how rocks can be pulverized by nature's agents which have no iron in them. Describe soils according to their chemical condition. Explain capillary attraction. How are crops benefited by this natural law? Give some of the characters of soils. What is the best soil as to its physical condition for a seed-bed? Describe soils according to their physical condition. What is humus? How do you account for there being sandy soils in one place, gravel in another, and clay soils in another?

THIRD DIVISION.

How may the analysis of the soil be advantageous to a farmer? What do you understand by the active and dormant portions of the soil? How can a farmer render the dormant portion active? Explain how this is brought about. How can a farmer increase the feeding ground of plants without extending the boundary lines? What other means beside tillage is adopted to get air into the soil? What are the effects of drainage upon clay soils? How is the atmosphere warmed? What increases the power of the air to hold moisture? What effect has this natural law in the summer time upon a country having a bare surface? State the chief objections which have been urged against subsoil drainage. Give your reasons for considering these objections untenable. How can the bad character of soils be cured or made better? What are the virtues of the double silicates? What kind of vegetation can only grow upon soil newly formed from rocks? What substance are found in a fertile soil that are not found in the primitive rocks? Where did they come from, and how did they get in the soil? Why does soil lose weight when burned? What does the lost weight represent? Explain how the first soil was prepared for the higher class of vegetation. Why are clover crops valuable to the soil? How is a sandy soil benefited by clover? How is a clay soil benefited by clover? What is the best method of applying manure to light soils?

FOURTH DIVISION.

WHAT substance in our soils is most abundant? Why are the phosphates so valuable to all soils? What substance is generally found united with silica? Is it found among the ashes of plants? Then what is its use to vegetation? Suppose plant food to be abundant in the soil, poisonous matters absent, and climate suitable, what is yet required to develop the capabilities of the soil? Explain what you mean by proper tillage. To what has Liebig compared the operation of the plow? What agencies are always ready to help the farmer, which require neither pay nor rest? Explain the action of each. Do plants receive any free nitrogen from the air? How does the common earth-worm benefit the farmer? Give your reasons for taking spade cultivation as the model. Describe a plow pan; a lime pan; an iron pan. What does the Scotch farmer sometimes use as a subsoil plow? Give your reasons in favor of a steam plow. What other implements are used in cultivation? Explain the use of each. What are the three essential requirements for the germination of seed? Explain these. Give your reasons for the necessity of a dry seed-bed. Why should the fine soil be closely pressed around the seed?

FIFTH DIVISION.

OF how many elements is the world and all that is therein built up? How many of these are metals? What are the other fifteen? How many elements are of importance to agriculture? How many of these are metals? What element forms the chief part of all plants? What element forms nearly half the substance of the whole globe? What proportion of the air is nitrogen? Which is the lightest of all the elements? Name the metals useful to agricultural crops. How are acid-oxides formed? Name the bases. How is a salt formed? What salt is formed by the direct union of two elements? What is quicklime? How is quicklime affected when exposed to the air? Why do masons cover lime after slaking it? What is the most valuable salt that can be applied to the land? Give your reasons. What causes dissolution of plants and animals after death? To what substances are the softer parts reduced? If decay

takes place on the surface, what becomes of the gases? If in the ground, what becomes of them? What becomes of their mineral substances? Do plants feed upon decaying matter direct? What changes must it undergo before they will accept it? What plants feed upon decaying matter direct? Describe a "fairy ring" and tell what causes it. How can a farmer aid the chemical changes in the soil?

SIXTH DIVISION.

WHEN is a soil said to be exhausted? Give the causes of exhaustion. How can fertility be restored? Why does exhaustion not take place in forests and prairies planted by nature? How may exhaustion be delayed for a long time? How many pounds of inorganic matter are removed from an acre by an average of wheat, turnips, or clover? What are the remedies for exhaustion? What is meant by fallow? Why is it not advantageous to keep a light, open soil fallow? What are the most profitable crops for this location? What is meant by a rotation of crops? Give a four years' course, and your reasons for its selection. What principles must guide you in determining upon a rotation of crops? What practical considerations favor a rotation of crops?

SEVENTH DIVISION.

WHAT is the great remedy for exhaustion? What do you understand by the term manure? What are the three principal modes in which manure acts? Give the special advantages derived from green manure, barn-yard manure, lime manures, artificial manures. Does the sheltering of barn-yard manure pay? What is its great feature as a manure? How much soluble plant-food is in a ton of barn-yard manure? Do artificial manures meet all the requirements of the soil? How may barn-yard manure be enriched? What informs the farmer that the manure heap is losing ammonia? State how he can avoid the evil. Give Lord Kinaird's experience with sheltered and unsheltered manure. What is a compost heap? Give Thouvenel's method of producing the nitrate of potash. What would be the effect of applying lime and barn-yard manure together on

the surface of the land? Give a summary of the effects of lime to the soil. What are artificial manures? What is guano? From what other sources besides bones do we get phosphates? What manures supply plants with albumen, gluten, and casein? What is the most important influence of common salt? Why is tanners' bark not valued by farmers? How can sawdust be rendered very serviceable? With what is guano generally adulterated? With what is bone-meal adulterated? How can the adulteration be detected?

EIGHTH DIVISION.

WHAT qualities should seed possess? Why is turnip seed better for a crop when it is two years old than one year old? Explain how moisture finds its way into seeds. What is the effect of seed becoming "dirty?" Trace the germination of a grain of wheat till it becomes a plant able to get food for itself. Trace in the same manner the germination of a pea, and a turnip seed, and state what is peculiar to each. Give the uses of roots to plants, and tell how they go down into the soil. What is the effect of a hard and close subsoil? What does this teach the farmer? Describe the stem and its uses. What organs prepare the food taken in by the plant for assimilation? Describe a leaf and its uses. Can we tell how a leaf manufactures the food for assimilation? Describe the manufacture of sugar in a beet. Describe the flower of a turnip, a pea, and wheat. What is meant by cross-fertilization? Why do some plants have bright flowers? What is the end and aim of the entire life of a plant?

NINTH DIVISION.

WHEN are the stem and leaves of a plant at their richest? Name some plants which the farmer allows to complete their round of existence, and some which he does not. What is meant by pedigree seed? To what family do wheat, corn, oats, rye, and barley belong? To what family do the cabbage, turnip, and mustard belong? To what family do the beet and celery belong? To what family do the carrot and parsnip belong? What is the derivation of the word cereal? What

crop may be considered the sheet-anchor of American farmers? Why? Describe the habits of the wheat plant. What is the best cultivation for it? Explain the process of tillering. When is the best time to cut wheat for milling purposes? When for seed? Give your reasons. When is the best time for manuring for wheat? What is meant by a change of seed? When is the best time to cut grass for hay? Why? Give four particular points that should never be overlooked by a farmer in making hay. What is a silo? What is ensilage? What is the use of the silo? In what countries may it prove profitable? Why may it not be profitable to the farmers of the United States? Give some points of excellence obtained by the growing of a clover crop. Relate the experience of a farmer who covered the young grass lightly with straw in winter.

TENTH DIVISION.

FOR what are American agricultural implements noted everywhere? Who produced the first practically useful reaping machines? Trace the improvements of these machines to the present day. Give your reasons for believing that the reaper and binder machine is the most valuable implement ever given to the American farmer. When should a farmer select a low-down reaping machine? What should govern a farmer in selecting a reaping and binding machine as to its breadth of cut? Name some of the points of excellence never to be overlooked in selecting a reaper or any other farm implement. What particular point must the farmer not overlook in selecting a mower? Why?

ELEVENTH DIVISION.

NAME some of the pests of the farm. To what kingdoms do they belong? What is a weed? Explain how weeds injure crops. What do some weeds tell the farmer? What weeds tell people who pass a farm that the occupant is lazy and thriftless? What are fungi? What encourages their growth? Why is seed-wheat sometimes steeped in a weak solution of sulphate of copper (blue vitriol) before sowing? Are birds friends or enemies to farmers? Give your reasons. How can

we best escape the ravages of the cut-worm? Describe a wire-worm. What is the most effective remedy for protecting crops against damage by insects? When may a farmer reasonably hope to be rewarded with good and profitable crops? Name some of the causes which render farming unprofitable. What is ventilation? Why is it a necessity in every building? Why is an undivided elevation in the roof worthless? How can you remedy the fault? When is the best time to cut timber? Why? Why should it not be cut in the spring? If all the standards of weights and measures be lost, how could they be restored? Explain how you could restore the inch; the pint or gallon; the pound.

VOCABULARY.

- ABSORB**, (*absorbere*, to swallow or drink up.) To drink up as a sponge.
- AGRICULTURE**, (*ager*, a field; *colere*, to till.) The cultivation of a field.
- ACCUMULATED**, (*ac*, to; *cumulus*, a mound or heap.) Collected into a heap.
- AERATED**, (*aer*, air.) Exposure to the free access of air; filled with air by force.
- ALIENATED**, (*alienare*, to remove; *ate*, to make.) Transferred to another; as the mineral substances contained in the wheat that is sold, being derived from the soil, are alienated or transferred.
- ALLEVIATE**, (*al*, to; *levis*, light.) To make a burden lighter or easier.
- ALLIANCE**, (*alligare*, to bring together.) The union between individuals or substances.
- ANALYSIS**, (Gr. *analuo*, to unloose.) The resolving or separating of substances into their elements.
- ANIMATED**, (*animus*, life; *ated*, made.) Possessing life and volition; able to move from place to place.
- ARTIFICIAL**, (*ars*, art; *facere*, to make; *al*, belonging to.) Anything made by the art or skill of man.
- ARABLE**, (*arare*, to plow; *ble*, fit to be.) Land capable of being plowed.
- ASSIMILATE**, (*as*, to; *similis*, like; *ate*, to make.) To make into a like substance; as food is converted into the likeness of the component parts of the animal or vegetable taking it.
- AUTOMATICAL**, (Gr. *automatos*, self-acting; *al*, pertaining to.) Machinery which controls its own movements is said to act automatically.
- AVAIL**, (*a*, on; *valere*, to be strong.) To be strong, so as to give help; to be of advantage.
- BIENNIAL**, (*bi*, two; *annus*, a year; *al*, belonging to.) Pertaining to two years; a plant which completes its course of existence in two years.
- BLANCHED**, (*blanc*, white.) Whitened, as the leaves of a plant when light is excluded.
- CALCAREOUS**, (*calx*, lime; *ous*, abounding with.) Abounding with lime.

- CAPILLARY, (*capillus*, a hair; *ary*, pertaining to.) Resembling a hair; a tube with an opening minute in diameter, though long, as in the hair of the head.
- CHARGED, literally means to lay on a load; loaded. Cargo, car, carriage, cart, chariot, etc., come from the same root, and convey a similar notion.
- CHART, (Gr. *kartes*, paper made from the Egyptian papyrus.) A writing. [This term is applied to a marine map, having ports and places on the coast located with precision.]
- CHEMICAL, (Gr. *kumikos*, concerning juices.) When different bodies unite, not mix, as sugar and water, they are said to be chemically united.
- CHLOROPHYL, (*chloros*, light-green; *phulon*, a leaf.) Vegetable-green, caused by the action of the sun upon the jelly-like substance found in every living plant.
- CONJUNCTION, (*con*, together; *junctum*, joined.) Joined together, or closely connected.
- CONTINUOUS, (*con*, together; *tenere*, to hold.) Holding together; uninterrupted succession.
- CONVERTED, (*vertere*, to turn.) Turned or changed from one substance into another; as starch is turned to sugar in a plant by a process of nature unknown to man.
- CREDIBLE, (*credere*, to believe; *ble*, fit to be.) Fit to be believed; worthy of belief.
- CRUCIFERÆ, (*crux*, a cross; *ferre*, to bear.) Plants having the four petals of their flowers in the form of a cross; the turnip and cabbage belong to the family cruciferæ.
- CULTIVATION, (*cultum*, tilled; *tion*, the act of doing.) The various processes employed to break and mix the soil to enable the air to enter it and render available the plant food in it, and also to enable the roots to grow in all directions without hindrance in their search for nourishment.
- DECADE, (Gr. *deka*, ten.) A period of ten years.
- DECAY, (*de*, down; *cadere*, to fall.) The falling down of a body, either animal or vegetable, in its progression to dissolution.
- DECIDUOUS. Falling down. Trees which shed their leaves in autumn are known as deciduous trees.
- DELETERIOUS, (*delere*, to destroy; *ous*, full of.) Very destructive; anything hurtful or injurious.
- DELICATE, (*delicia*, pleasing to the senses.) Beautifully fine.
- DEMOLITION, (*de*, down; Sax. *mööl*, meal.) Reduced to fineness, like meal. Mould, mill, melder, (Ger. *müller*,) melt, etc., are from the same root and convey the same notion.
- DESCENDS, (*de*, down; *scandere*, to climb.) Passes from a higher to a lower place.

- DESICCATING, (*desiccare*, to dry up.) Drying up; as air, not having its due proportion of moisture, absorbs water.
- DESTRUCTION, (*destructio*, a pulling down.) The changing of the form of a body into another form. [In referring to the soil and animal or vegetable bodies, it never means annihilation, as it does when speaking of laws and constitutions.]
- DEXTRINE, (*dexter*, the right hand.) The clear, gum-like substance made from starch; so named because its solution directs a polarized ray of light to the right hand when it passes through it. (C. 6, H. 10, O. 5.)
- DIASTASE. A substance which is developed by germination, which has the remarkable property of changing starch into dextrine, and, ultimately, into sugar. The great aim in the malting process is to produce this diastase. Malting barley should contain abundance of starch and the germ largely developed.
- DIFFUSE, (*diffundere*, to scatter.) The spreading of a liquid in every direction; as water, in a well-drained clay loam soil, is diffused in that kind of soil like mist or fog in the air.
- DIMINISH, (*diminuere*, to lessen.) To become gradually less.
- DISINFECTANT, (*dis*, not; *infectum*, tainted.) That which destroys poisonous exhalations or germs, such as sulphur fumes, chlorine from salt, and the silicates in clay.
- DISSOLVE, (*dissolvere*, to take to pieces.) To change a solid substance to a liquid form by water, acid, or heat.
- DORMANT, (*dormire*, to sleep.) In a state of inactivity. A term applied to substances insoluble in the soil, but which may become soluble by proper cultivation.
- EARS. The top part; that part of certain kinds of plants which produces the flower and contains the seed.
- EARTH, (Heb. *aradh*, to gnaw; Sax. *yerd*, the soil.) The particles eaten from the rocks, which constitute the mold or soil on the surface of the land.
- ENORMOUS, (*e*, out of; *norma*, a rule; *ous*, much.) Much beyond the general rule. Applied to what is excessive in size or extent.
- ENSILAGE, (*en*, into; Fr. *silo*, a pit.) Crops put into a pit in a green state, firmly and closely packed, and air excluded.
- EVAPORATE, (*e*, out of; *vapor*, steam.) Water made to pass away in the form of steam.
- EXHAUSTING, (*exhaurire*, to empty.) Taking out all of a substance; making the soil barren.
- FALL. The time of year when the falling of leaves becomes general; autumn.
- FERREOUS, (*ferrum*, iron; *ous*, full of.) Abounding with iron in composition with other substances.

FERTILE, (*fero*, to bear.) Fruitful; soil which brings forth crops abundantly.

FIBERS, (*fibra*, a thread.) The fine, thread-like roots of plants; or any thread-like substance.

FOISON. Nutriment. [Some think the word is derived from the Latin *fundo-fusi*, and to mean a pouring; hence, *abundance*. In those localities where the Anglo-Saxon language yet prevails it is used to signify nutriment, or that which nourishment produces—*strength*. When a turnip has developed its cellular portion more rapidly than it could elaborate its nourishing juices, it becomes corky; they then say it is *foisonless*. When an animal or plant is well nourished, they say it has *foison* in it; hence, *strength*.]

GAS. An elastic aëriform fluid. Guest, ghost, gæst are from the same root, conveying the notion of airy spirits. In this sense the soul was regarded as the guest of the body.

GENUS, (*pl. genera*, a race or family.) A group of plants which agree as regards the organs of fructification and reproduction and a general resemblance of habit.

GEOLOGY, (*Gr. ge*, the earth; *logos*, a discourse.) The science which treats of the mineral constituents of the earth, their formation, position, and direction.

GERMINATION, (*germen*, a seed.) The growth of a seed; air, warmth, and moisture must be present to cause the growth.

GRANITE, (*granum*, a grain.) A primitive rock, so named from its being apparently composed of small pieces or granules.

HORIZON, (*Gr. orizon*, to bound.) The boundary of vision, or where the earth and sky seem to meet.

HORTICULTURE, (*Gr. ortus*, an inclosure.) The cultivation of a garden.

HUMUS, (*humus*, soil.) The black substance in the soil formed from animal and vegetable remains; hence, called organic matter.

IGNORE, (*ignosco*, to be ignorant of.) To pass by without noticing, as if the person or thing had no existence.

IMPREGNATED. The virtues of one thing infused into another; as the pollen of the flower is infused into the pistil.

INFALLIBLE. Entirely exempt from mistake or failure.

INFLUENCE, (*influere*, to flow into.) A power whose operations are invisible; to be judged only by its effects.

IRRIGATION, (*ir*, into; *rigare*, to water.) The operation of causing water to flow in distributing channels over the field to nourish plants.

LUCID, (*lux*, light.) Made clear to the mind.

MANUFACTURE, (*manus*, the hand; *factum*, made.) Made by hand. [It is now applied to the making of cloth and wares of all kinds which are produced by machinery from the raw material.]

MANURE, (*manus*, the hand; Fr. *ûre*, over.) Worked over by hand. It was originally applied to land made fertile by being worked by manual labor, but it is now used as a name for any substance, whether of animal, vegetable, or mineral origin, which has the effect of making the land fertile.

MATURITY, (*maturus*, ripe.) The completion of growth in plants to ripeness. Applied to a promissory note, it is the date when it is due, or the time when the maker promised to pay.

MARINER'S COMPASS. An instrument used for directing the course of a ship at sea, and consists of a card marked with 32 points of direction, fixed to a magnetic needle, which always points to the North, the variations excepted. The needle, with the card attached, is supported on the fine point of a pin, and is arranged so as to remain in a horizontal position, independent of the tossing or rolling of the ship.

MAXIMUM, (superlative of *magnus*, great.) The greatest abundance.

MEMBRANE. A thin, translucent skin.

MICROSCOPE, (*micros*, small; *scopco*, to view.) An instrument used to examine very minute things.

MINIMUM, (superlative of *parvus*, small.) The least quantity possible.

MOISTURE. Water scattered or diffused as a mist.

MOULD-BOARD. That part of a plow which receives the soil or mould from the share, and, by its construction, raises, turns, and deposits it at an angle of 45 degrees, because by that angle the greatest amount of surface is exposed to the sun and air. This part of the plow is so named because it was continued to be made of wood long after the coulter and share were made of iron or steel; and, although it is now universally made of steel, it yet retains its ancient name as a relic of the primitive methods of agriculture.

NEUTRALIZE, (*neuter*, neither; *ize*, to make) To render inactive the peculiar property of any substance.

OIL-CAKE. A cake formed by the immense pressure of certain kinds of seeds for forcing out the oil contained in them—usually linseed, rape, and cotton seed.

ORGANIC, (*organon*, a member.) Belonging to a member; any substance which formed the soft part of a plant or animal; it includes all the substances found in a plant except the mineral.

OVULE, (*ovum*, an egg; *ule*, little.) A minute egg or germ.

PAPILIONACEOUS, (*papilio*, a butterfly.) A family of plants whose flowers are shaped like the wings of a butterfly, as those of the pea, bean, and clover.

- PISTIL.** The organ of a flower which contains the ovule. It is so named from its resemblance to the pestle of the apothecary.
- PER CENT.** For or by the hundred. The term is used for its convenience in expressing a ratio; thus, 5 per cent. represents 5 for a hundred, 10 per cent. 10 for a hundred; at 5 per cent. 50 would give $2\frac{1}{2}$, because if 100 gave 5, 50, being the half of a 100, it gives the half of 5, or $2\frac{1}{2}$.
- PERFUNCTORY.** Careless; in a slovenly manner.
- PRECEDE**, (*pre*, before; *cedere*, to walk.) To go before; as clover should precede wheat.
- PRECIPITATING**, (*pre*, before; *caput*, the head.) Rushing headlong. [It refers to the descending of a substance which has been mechanically mixed or chemically united, such as takes place with moisture in a crowded room; the air, being warm, holds much moisture in diffusion, which, upon the admission of cold air, is quickly condensed and precipitated; or, when a piece of metal is held in solution in a strong acid, by the application of another substance which neutralizes the acid, the metal is precipitated to the bottom of the vessel.]
- PRINCIPAL**, (*princeps*, the chief.) The first in rank.
- PRINCIPLE.** The operative cause; an admitted truth; equivalent to the term axiom in mathematics.
- PROGRESSIVE**, (*pro*, forward; *gressus*, walked.) Advancement step by step; a continued work, in contradistinction to an *act* or *deed* performed at once.
- PROMOTES**, (*pro*, forward; *movere*, to move.) Moves forward; that which encourages or advances.
- PROPORTIONATE**, (*pro*, for; *portio*, a share; *ate*, to make.) Share for or equal to share; that which is adjusted to something else according to a fixed rate.
- PROTOPLASM**, (Gr. *protos*, first; *plasma*, shape.) First form or shape; a jelly-like matter, generally considered the life substance of the plant, and found in all living plants.
- PULVERIZE**, (*pulvis*, dust; *ize*, to make.) To reduce hard substances to powder.
- PUNGENT**, (*pungere*, to sting.) That which affects the tongue or eyes, as if pierced with sharp points, such as is produced by acid or ammoniacal salts.
- RESISTANCE**, (*resistere*, to withstand.) That power of a body to withstand force.
- RUMINATE**, (*ruminare*, to repeat.) The process of masticating by such animals as cattle, sheep, deer, etc., whereby the grass and herbage which was swallowed while grazing, having undergone a cooking process in the first stomach, is brought back to the mouth and thoroughly masticated. To cook food for ruminating animals is now considered by many persons to be a superfluous work.

- SCIENTIFIC, (*scientio*, knowledge.) Knowledge established on the principles of evidence.
- SLAKE, (Sax. *sleac*, to quench.) To pour water on lime; making a hydrate of limo slakes it.
- STAGNATE, (*stagnare*, to become motionless.) To cease to flow, as water in a slough or pond.
- STAMEN. A thread; the organ of a flower which produces the pollen, and consists of the filament and anther.
- STARCH, (Sax. *stark*, stiff or strong.) The farina of various plants; insoluble in cold water; but when boiling water is poured over it, makes a viscid substance used to stiffen linens, etc.
- STIMULANT, (*stimulus*, a goad or instrument used in driving cattle.) In agriculture it is a name applied to substances put in the soil to make it yield, but which add no plant food.
- STRATUM, (*pl. strata*.) A layer or seam, as a layer of rock, a seam of coal.
- TEMPERATURE. The state of the earth, air, or any body, as to its heat or cold, indicated by a thermometer.
- THERMOMETER, (Gr. *thermos*, heat; *metron*, a measure.) An instrument by which the heat or temperature is measured, which is designated by degrees.
- TORRENT, (*torrere*, to burn.) Violent action; as a great rush of water down a steep declivity.
- TRANSPORTED, (*trans*, beyond; *portare*, to carry.) Carried away, as soils are carried away by floods from the rocks from which they had crumbled.
- VEGETABLE, (*vegere*, to grow.) Any and every plant which grows; commonly used, however, to designate plants grown in the garden for culinary purposes.
- VIGOROUS, (*vigor*, energy of life.) Activity in the growth of plants, or spirited and energetic activity of animals.
- VIZ., (contraction of *videlicet*.) The equivalent of *to wit*; namely.
- VOLATILE, (*volare*, to fly.) Any substance which readily escapes or flies away, as ammonia or the non-essential oils.

